Report Issued:

June 22, 1992

BIRD MORTALITY IN RELATION TO THE MARE ISLAND 115-kV TRANSMISSION LINE: FINAL REPORT

1988-1991

Prepared for

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June 1992

PG&E Report Number 443-91.3

EXECUTIVE SUMMARY

Under Letter of Permission issued by the U.S. Army Corps of Engineers (COE) in April 1988, the U.S. Navy contracted Pacific Gas and Electric Company (PG&E) to build a 115-kV transmission line to serve the Mare Island Naval Shipyard. The permit required the Navy to conduct a three-year monitoring program to determine the impacts of the transmission line on birds. PG&E strung the 7-km transmission line in July 1988 and began carrying out the monitoring study one month later. The first two years of study were summarized in earlier reports (Dedon et al. 1989, Dedon et al. 1990) and revealed that bird collisions did occur with the 115-kV transmission line and with a 12-kV transmission line sharing the same poles for a portion of the transmission line route. This report summarizes three years of bird mortality monitoring (August 1988-May 1989, July 1989-May 1990, and July 1990-May 1991) and two years of bird flight pattern studies (October 1989-May 1990 and August 1990-May 1991).

We carried out twice-weekly searches within two 61-m-wide transects under the transmission line and two other comparison transects. One transmission line transect is 1.6 km long and is parallel to the shore of a salt evaporation pond (salt pond transect). Here, the transmission line is underbuilt with a 12-kV distribution line sharing the transmission line poles. The other transmission line transect traverses a hay field for about 4.8 km (hay field transect). One comparison transect (CTA) consisted of two spans of the 12-kV distribution line immediately north of the termination of the transmission line. The other comparison transect (CTB) is on a nearby levee with no powerlines.

Bird specimens were collected after recording specific information about them in the field. Because of a high rate of scavenging and possibly predation, most of the specimens were only feathers or other bird parts. We consulted with experts to assist us in identifying bird specimens. Necropsies were performed on all intact specimens by the California Department of Fish and Game Wildlife Investigations Laboratory.

For Years 1, 2, and 3, we collected 309, 262, and 214 bird specimens, respectively. The bird specimens represented at least 86 species. In all three years, most of the specimens were found within the salt pond transect (81%). With the exception of CTB, we found fewer birds in each successive year. In CTB, the smallest number of specimens were recovered in Year 2.

Necropsy identified the cause of death for 75, 35, and 31 birds in Years 1, 2, and 3, respectively. The causes of death were cholera, trauma, gunshot, malnutrition, and non-trauma. We also found 6, 7, and 2 injured birds in Years 1, 2, and 3, respectively. We assume that trauma and injuries resulted from collisions with the transmission or distribution lines, or with a guy wire. We conducted tests to determine biases used for calculating an estimate of total dead birds and total collisions. Search bias tests involved planting birds and bird parts prior to searches and recording the number recovered. Scavenger bias was learned from placing dead birds in the transects and observing how quickly they were removed by scavengers. Habitat bias was derived from a span-by-span visual estimate of the proportion of area that can be searched effectively. Collision estimates were made using a bias factor from the literature. Our estimated total bird mortality associated with the powerline for Year 1 was 258 birds in the hay field transect and 627 birds in the salt pond transect. In Year 2, we estimated 335 birds in the hay field transect and 878 birds in the salt pond transect. In Year 3, we estimated 176 birds in the hay field transect and 1,308 birds in the salt pond transect.

In Years 2 and 3, we conducted daytime flight pattern studies for three consecutive days each month. In Year 2, night surveys were conducted on three consecutive nights from sunset to around 0100 h and resumed from 0430 h to sunrise. Night observations were conducted on two consecutive nights in Year 3 and were continuous from sunset to sunrise. Differences in altitude and reactions were observed for different species and species groups. During the day, non-passerines generally flew at altitudes above the 115-kV transmission line and passerines flew at altitudes within or below the height of the lower distribution powerlines. Birds flying at night reacted less to the powerlines than birds crossing the lines in the day. Most of the night flights occurred just after sunset and just before sunrise. Nine collisions were witnessed during the night survey and no collisions were observed during the day survey.

The relation between weather variables, local bird population size, and the level of bird mortality was investigated using data from Years 2 and 3 of the study. Local bird density was estimated from monthly pond censuses and flight surveys. Stepwise multiple regression analyses were conducted for three groups: wintering waterbirds (ducks, grebes, and coots), shorebirds, and "landbirds". The proportion of variation in bird mortality explained by variations in weather and bird density ranged from 18 to 25%. When years were considered separately the proportion of variation explained was around 60%. Shorebird density was the only significant predictor of mortality for shorebirds. Bird density was weakly associated with mortality for wintering ducks and landbirds. Landbird mortality increased with wind. Duck mortality was influenced by several variables which seemed to indicate unsettled weather.

The significance of bird mortality caused by the Mare Island transmission line is difficult to determine. It is a function of species population size, population turnover during migration, reproductive success, and the degree to which powerline mortality replaces other mortality factors. However, our data allow a best guess of the vulnerability of different bird groups to powerline collisions in our study area. For hunted species, variation of hunting success below regulated bag limits likely has a much greater effect on populations than powerline mortality. Of the 15 species of shorebirds, the most commonly collected species were black-bellied plover, western sandpiper, and dunlin. These species appear to be more vulnerable to powerlines than other shorebirds. Three species of rails (California black, Virginia, and sora) were collected during the study and may be vulnerable to powerline mortality because they are resident species. Gulls and terns, passerines, and raptors were collected infrequently in comparison to their likely populations and are thus probably not adversely affected by powerlines.

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Section 1

INTRODUCTION

This report summarizes the results of three years of study of the impacts on birds of a 115-kV transmission line that provides backup power to the Mare Island Naval Shipyard in Vallejo, California. The 4.5-mile transmission line was released for operation on November 17, 1988. Pacific Gas and Electric Company (PG&E) built the transmission line under contract to the Navy. The Navy also contracted with PG&E to complete this study because of PG&E's experience in studying bird/powerline interactions. The study was conducted because of concern that birds would collide with the new powerline and be killed. Electrocution of birds by the powerline was not expected to occur because of the distance between the conductors (wires).

The methodology developed by PG&E and the Navy and approved by the U.S. Army Corps of Engineers (COE) in conjunction with the U.S. Fish and Wildlife Service (USFWS) was designed for a tiered implementation based on the level of observed bird mortality. In the first year of the study, only bird mortality was recorded within transects under the powerline and within comparison transects. The results of the first year of study supported the need for a flight pattern study to obtain a better perspective on the impacts of the powerlines on different bird species. This report presents the findings of the three years of mortality searches (August 1988 through May 1989, July 1989 through May 1990, and July 1990 through May 1991) and the results of two years of flight pattern study (October 1989 through May 1990, and August 1990 through May 1991).

REGULATORY BACKGROUND

The Navy prepared an Environmental Assessment and Finding of No Significant Impact for construction of this project across Cullinan Ranch. The Navy evaluated a variety of alternatives and determined that an above-ground transmission line was the preferred alternative. The Environmental Assessment concluded that underground 115-kV transmission lines were technically infeasible for the 4.5 mile route.

During the interagency coordination process, the COE advised the Navy that the project required a Letter of Permission from the COE under the Rivers and Harbors Act of 1899 (33 U.S.C. 403) because the proposed transmission line crossed navigable waters of the United States. The COE made this determination because the area was a historically navigable waterway, and therefore new utility poles might have some effect on future navigation if the area was ever reconnected to the San Francisco Bay. At the time of transmission line construction, the area had been diked and in agricultural use for approximately 80 years.

The USFWS objected to the COE issuing a Letter of Permission on the basis that a significant number of migratory birds would be killed by collisions with the new transmission line. The USFWS also indicated concern that the project would encourage urbanization of Cullinan Ranch, and that the USFWS was considering acquiring Cullinan Ranch as an addition to the National Wildlife Refuge System. The USFWS recommended that the new transmission line be placed underground.

After extensive discussions between the Navy and the USFWS, the COE issued Letter of Permission No. 17023E24 on 4 April 1988 providing the Navy authorization to construct a 115kV transmission line across Cullinan Ranch. Three special conditions related to migratory birds were attached to this Letter of Permission. These were:

a. The permittee shall conduct a three year monitoring program approved by the COE in consultation with the USFWS, to determine if adverse impacts to migratory birds and/or endangered species have occurred. Development of the monitoring program shall be finalized and approved prior to completion of the authorized transmission line. The monitoring shall begin immediately upon completion of the construction activity.

b. The permittee shall investigate and implement, practicable mitigation measures, approved by the COE, in consultation with the USFWS, to eliminate any unacceptable adverse impacts resulting from the authorized transmission line. If any federally listed, threatened, or endangered birds are incidentally taken, consultation pursuant to Section 7 of the Endangered Species Act, shall be initiated immediately.

c. If the USFWS should acquire property adjacent to the authorized transmission line, for the purpose of land management as a wetland and bird refuge, and the subject transmission line is found to adversely impact USFWS management objectives, the permittee shall consult with the COE and the USFWS for the purpose of taking corrective actions to diminish the adverse impacts of the transmission line on USFWS management objectives.

Special condition "a" has been completed with publication of this report. The continuing applicability of special conditions "b" and "c" will be determined between the Navy, the COE, and the USFWS based on review and discussion of this report. PG&E expertise may also be required to determine if conditions "b" and "c" have been fulfilled. The USFWS acquired the Cullinan Ranch property adjacent to the transmission line in 1990.

Section 2

STUDY AREA

The 115-kV transmission line under study begins at a junction with the Vaca-Ignacio transmission line at the northwest corner of the Cullinan Ranch hay field in Solano County, California (Figure 2-1). From this junction, the transmission line heads south for 1.6 km (18 spans) until it intersects Highway 37. In this section, an existing 12-kV distribution line serves a salt pond pump. Under this portion of the powerline is a ditch formed by a levee on the west side and a hay field on the east side. This ditch is approximately 30 m wide and supports ruderal vegetation and saline wetland vegetation including radish, mustard, salt grass, and pickleweed (Figure 2-2) (scientific names are listed in Appendix A). We established a "salt pond" transect under this portion of the transmission line. The transect is 61 m wide (200 ft) and is centered under the middle conductor (Figure 2-3). The western edge of the transect is on the levee and borders a salt evaporation pond managed by the Leslie Salt Company. Shooting is permitted on the levee and the area is open to public hunting. The eastern edge of the transect lies within the Cullinan Ranch hay field.

At the intersection with Highway 37, the transmission line turns in a southeast direction and parallels the highway for 4.8 km (58 spans) and traverses the hay field about 30-40 m from the edge of the highway (Figure 2-4). Under this portion of the transmission line, the ground is very flat and was farmed for oat hay. Between the transmission line and the highway is a 10-m-wide ditch, which supports ruderal and saline wetland vegetation (with the same species as are in the ditch near the salt pond). Under this portion of the transmission line, we initially established a 61-m-wide (200-ft) "hay field" transect centered under the middle conductor (Figure 2-3). On October 4, 1989, the transect width was narrowed to 38 m to reduce the cost of the study. We compensated for this reduction when we estimated a total number of dead birds (see Methods section). The northern (actually northeastern) edge of the transect lies within the hay field and the southern edge is adjacent to Highway 37. An additional five spans (700 m) at the east end of the hay field continue across Highway 37, where the transmission line joins a substation in the Mare Island Naval Shipyard. These five spans were not included in the study area approved by the COE because low bird use was expected in this location.

We began searching a third transect, comparison transect A (CTA) on November 14, 1988. CTA is also 61 m wide and is contiguous with the northern portion of the salt pond transect. CTA is centered under a distribution powerline that continues north of the Vaca-Ignacio transmission line. CTA is 2 spans long (244 m). We included this transect to investigate the effects of the configuration of the conductors. The vegetation and topography are the same as the salt pond transect.

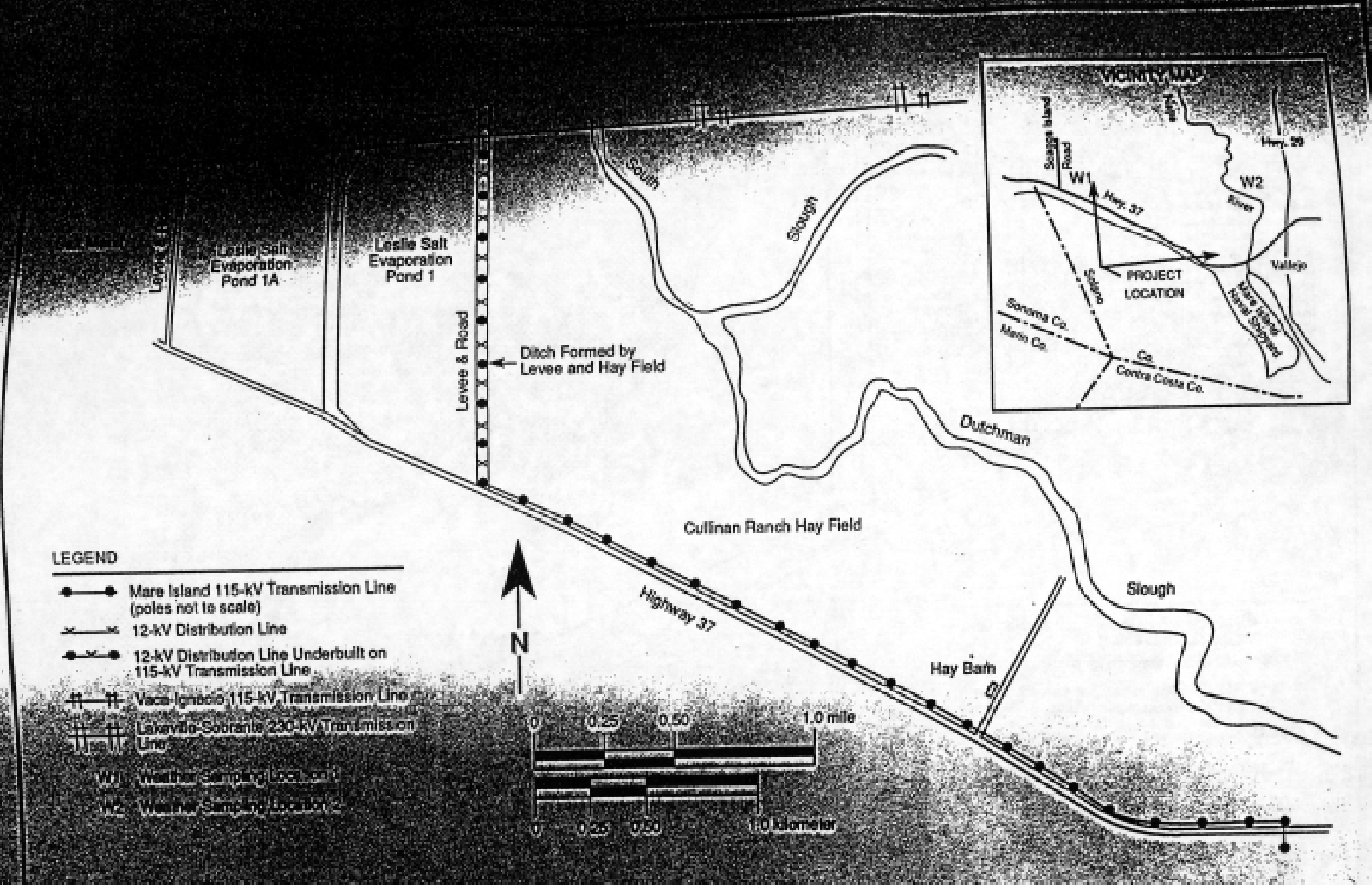

Figure 2-1. Mare Island transmission line bird study area.

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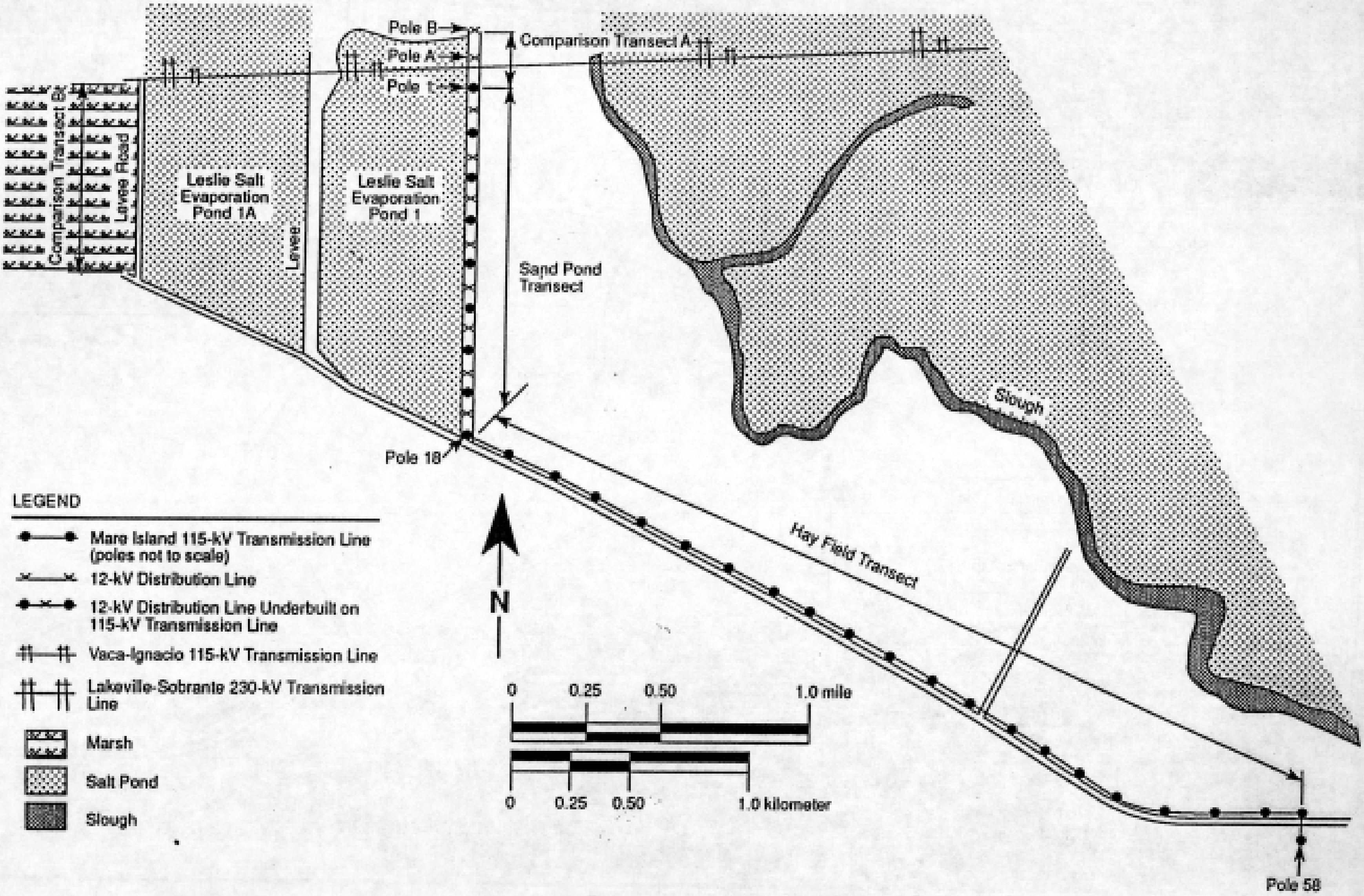


Figure 2-3. Schematic map of the hay field and salt pond transects, and the comparison transects A and B.

We also searched a fourth transect, comparison transect B (CTB), beginning on January 27, 1989. CTB is located on a levee bordering the west edge of salt pond 1A (Figure 2-3). This transect runs north and south 1,100 m between Highway 37 and the Vaca-Ignacio transmission line. CTB is approximately 20 m wide, with the east and west sides bounded by salt pond 1A and a salt marsh, respectively. We marked the distance south from the Vaca-Ignacio transmission line with flags spaced every 50 m. Except for the Vaca-Ignacio transmission line at the northern end, no transmission or distribution lines are near this transect. The vegetation in CTB is ruderal, consisting primarily of mustard, radish, and annual grass (Figure 2-5).

The 115-kV transmission line consists of three 13.26-mm-diameter ("4/0 aluminum") conductors, which are mounted on 1.5-m insulators attached to single wooden poles. The conductors are arranged in a triangular pattern, with the middle conductor at the apex and the two side conductors forming the ends of the triangle base. At each pole, the lower conductors are 17 m above the ground, and the top conductor is 19 m above the ground. Mid-span, the conductor heights range from approximately 14 to 16 m above the ground. The transmission poles within the salt pond transect also support three 12-kV, 4.11-mm-diameter ("#6 copper") distribution conductors. These conductors are 12-13 m above the ground at the poles and 9-10 m above the ground mid-span (Figure 2-6). Some of the poles are supported with guy wires.

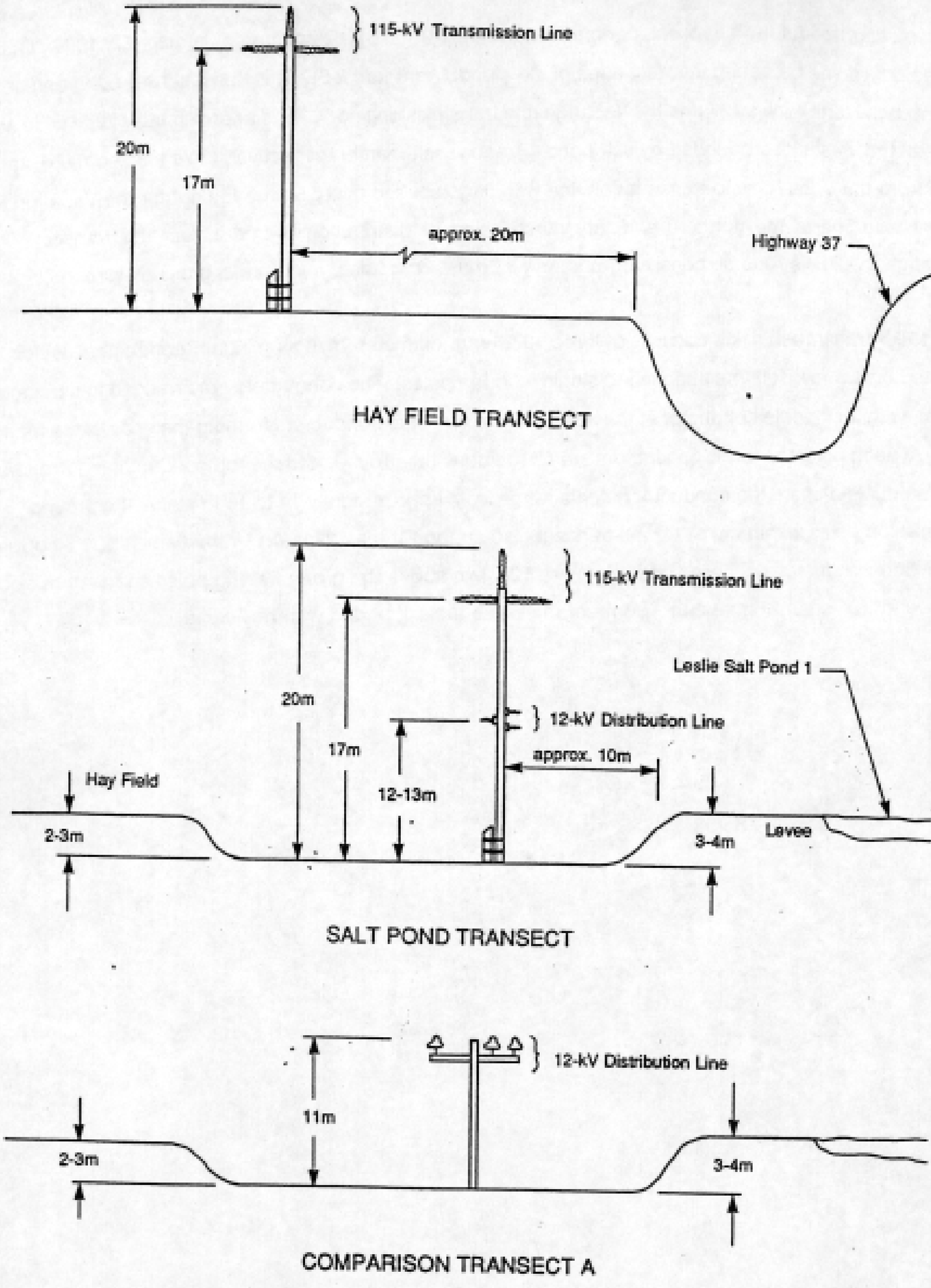


Figure 2-6. Transmission and distribution line configurations in the hay field and salt pond transects, and the comparison transect A.

Section 3

METHODS

BIRD MORTALITY MONITORING

Sampling Period and Intensity

We conducted two searches for dead birds per week for three years: Year 1 (August 25, 1988--June 1, 1989), Year 2 (July 19, 1989--May 31, 1990), and Year 3 (July 18, 1990--May 30, 1991). CTA and CTB were searched once a week in Year 1, and twice a week thereafter. The two searches per week were always performed on consecutive days to enable us to study the effects of weather and tides on mortality. This level of sampling intensity was also helpful for finding birds prior to scavenging. Approximately 65% of our search days were during or immediately following weather conditions suspected of affecting bird mortality (Table 3-1).

Search Method

Because we learned to expect more bird mortalities in the salt pond transect, by November 1988 we began every search day there (within 1 hour after sunrise) to look for dead birds before they became scavenged. Also, just prior to searching the salt pond transect on foot, we drove the levee road to look for obvious injured or intact dead birds that we could recover. We alternated the starting point of the salt pond transect each day between the north and south ends.

The salt pond and comparison transects were searched by two persons walking in a zigzag pattern on either side of the transmission center conductor to a distance of 31 m (20 m in CTB) perpendicular to the center conductor. The salt pond and comparison transects were always searched on foot.

The hay field was initially searched on foot, but from November 9, 1988 on we used all-terrain vehicles (ATVs) to search the hay field transect. Typically, the searchers drove at walking speed on the same side of the center conductor, searching half of the transect width, and then returned to the starting point while searching the other half of the transect. As stated above, the northern half of the hay field transect was narrowed to 8 m; however, we continued to search the full available width (approximately 19 m) on the south half. We were unable to search effectively the 12 m of this transect closest to Highway 37 because of tall vegetation, but we compensated for this habitat bias in deriving an estimate of total bird mortality.

When a specimen was found, searchers used a field data sheet to record the specimen number, transect, date, location, species, condition, time, detectability, whether or not it was flagged, photographed, or suitable for necropsy, plus any additional comments (Appendix B).

Table 3-1. Percentage of dead bird surveys conducted in periods of poor weather.

Weather Condition	Number of Days	Percent of Search Days
Precipitation on search day		
Year 1	12	14.3%
Year 2	7	7.5%
Year 3	13	12.5%
Precipitation on previous day		
Year 1	17	20.2%
Year 2	6	6.4%
Year 3	14	13.5%
Poor visibility on morning of search day		
Year 1	17	20.2%
Year 2	29	30.9%
Year 3	19	18.3%
Poor visibility on morning of previous day		
Year 1	20	23.8%
Year 2	29	30.9%
Year 3	19	18.3%
Cloud height less than pole height		
Year 1	8	9.5%
Year 2	5	5.3%
Year 3	10	9.6%
Low temperature (minimum <2.3°C)		
Year 1	9	10.7%
Year 2	15	16.0%
Year 3	15	14.4%
Windy on preceding day (maximum gust > 17mph)		
Year 1	9	10.7%
Year 2	13	13.8%
Year 3	20	19.2%
Windy on morning of search (wind speed > 5 mph)		
Year 1	15	17.9%
Year 2	14	14.9%
Year 3	15	14.4%
Search days with one or more conditions		
Year 1	48	58.3%
Year 2	69	73.4%
Year 3	66	63.5%

Specimens were photographed before they were collected to document the searchers' assignment of detection classes used for calculating a search bias. All specimens were collected (under authority of state and federal permits) and placed in labeled, reclosable plastic bags. The specimen number was preprinted on the label to eliminate the possibility of duplicate numbers. Specimens will be stored frozen at PG&E until at least September 1993. When birds had been scavenged, the searchers collected as much of the feathers and carcass as possible. In many of these cases, the smaller feathers were difficult to pick up completely, so searchers planted a metal flag so they would not mistake the feathers for a new mortality in future searches. The flags were removed on subsequent searches when the feathers they were marking were no longer visible. We also recorded incidental observations such as the presence of northern harriers.

We identified species immediately whenever possible. Because of scavenging, many bird mortalities were evidenced by feathers only ("feather spots"), or feathers with bones. In most of these cases, we attempted to identify species by consulting with experts at the University of California, Berkeley, Museum of Vertebrate Zoology. Injured birds were given to the Lindsay Museum (Walnut Creek, California) for rehabilitation.

Cause of Death

The Veterinary Diagnostic Laboratory at the University of California, Davis necropsied the first six intact birds in Year 1. Thereafter, we submitted 209 intact birds for necropsy to the California Department of Fish and Game's (CDFG) Wildlife Investigations Laboratory (necropsy results are presented in Appendix C).

MORTALITY AND COLLISION ESTIMATES

We estimated total dead birds and total collisions by following and elaborating on the procedure outlined by Faanes (1987). These estimates were a function of our searching ability (search bias), scavenger removal (scavenger removal bias), the area that could be searched within the transects (habitat bias), and the number of birds that could strike a powerline but continue flying outside the transects (crippling bias). We conducted field tests to derive the biases used to calculate the estimates. We had hoped to derive a crippling bias from our own observations of bird collisions during the flight pattern study; however, only nine collisions were observed during two seasons of flight pattern study and none of those birds were recovered in the transect. Consequently, we continued to use the same crippling bias used by Faanes (1987): 74% of the birds that hit a powerline continued flying out of the transect.

We computed a separate estimate of dead birds for each specimen collected. This was done because search bias varied by how obvious a bird was, and because scavenger removal and habitat biases varied over time and location. These biases and estimates were then totalled separately for the four transects and years of the study.

Search Bias

Search bias is a measure of our ability to find dead birds within the transects. The formula for calculating search bias for each specimen is:

$$SB_i = (1/PBF_i) - 1$$

where

SB_i = search bias of detection class i. Detection classes are described below.

PBF_i = proportion of birds found in detection class i, from those placed during field tests.

We also derived a 90% confidence interval around each detection class bias using the normal approximation to the binomial distribution:

$$PBF_i \pm 1.67\ SQRT(PBF_i\ PBNF_i/n)$$

where

$PBNF_i = 1 - PBF_i$ = proportion of birds not found in detection class i, from those placed in field surveys, and

n = number of placed birds in detection class i which were available to be found.

Consequently, a separate SB_i was derived for the mean and the upper and lower 90% confidence interval limits. Note that the confidence interval limits are asymmetrical around the mean SB_i because SB is an inverse function of PBF.

We conducted nine search bias field tests to derive PBF values (Appendix D). The tests were conducted by placing a known number of birds or feather spots in the study transect prior to the beginning of the search. In all but the first test, the searchers were unaware that they were being tested.

Specimens were assigned detection classes as follows:

Detection Class	Description of Specimen
1	Extremely difficult to detect; however, the finding still qualifies as a mortality. A specimen at this level of detection is difficult to see when you are looking directly at it. Note that small, well camouflaged birds could be assigned this code, as well as small camouflaged feather spots.
2	Very difficult to detect. You need to look nearly directly at the specimen. However, once found, the specimen is not very difficult to see.
3	Easy to detect, but not until you are fairly close to it (3-5 m).
4	Attracts your attention. This might include a wounded bird moving around, or a large feather spot left by a pelican or egret.

Figure 3-1 provides examples of dead birds assigned detection levels 1 through 4.

We used the results from search bias tests 3-9 to derive separate search biases for each detection class. Results from Tests 1 and 2 were not used because the searchers were aware they were being tested during Test 1, and scavengers may have removed planted specimens during Test 2. Each specimen found during the mortality searches was assigned a mean search bias and upper and lower limits of the 90% confidence interval.

Scavenger Removal

Scavenger removal is a measure of how quickly scavengers remove birds from the transects. It is expressed as the proportion of birds remaining from those that were placed within the transect during tests. The formula for calculating scavenger removal bias for each specimen is:

$$SR = [(1 + SB)/PNR] - (1 + SB)$$

where

SR = scavenger removal

SB = search bias

PNR = proportion of planted birds not removed by scavengers during period t corresponding to the date of collection.

Faanes (1987) assumed PNR was a constant 0.9 for each of his study areas. We calculated different PNR values that were appropriate for each transect and the number of days following the placement of test birds in the transects. Eleven scavenger removal studies were conducted (Appendix E). The tests were performed by placing whole birds of various species within the salt pond transect, hay field transect, CTA, and CTB. All birds were placed within 5 m of a pole (or flag within the CTB), with their locations noted. The status of the birds was then checked as indicated in Appendix E.

Habitat Expansion Factor

Portions of the transects were either inaccessible (due to water or topography) or, at times, overgrown with vegetation and could not be searched. We contracted with the farmer to mow and disc the hayfield transect in the spring of Years 1, 2, and 3 to improve searchability. Manual vegetation control was used in the salt pond transect and CTA in Year 1. Both herbicides and manual vegetation control were used in Year 2. No herbicides were used in the salt pond and CTA transects in Year 3, but limited manual weed control was initiated after the rain began to encourage vegetation growth. No vegetation control was initiated in CTB in Years 1 and 3. Manual vegetation control was used in CTB in Year 2.

For the purpose of estimating total bird mortality, a habitat expansion factor compensates for the proportion of area that is not actually searchable within the transect. The formula for calculating habitat bias (Faanes 1987) is:

$$HF = [(1 + SB + SR)/PS] - (1 + SB + SR)$$

where

HF = habitat expansion factor

SB = search bias

SR = scavenger removal

PS = proportion of the study area that was searchable.

For the hay field transect, salt pond transect, and CTA, we made a visual estimate of the proportion of searchable area for each of four "cells" within each span. The cells were arranged parallel to the conductors, with two cells on each side of the center conductor. Each of the cells were 15 m wide and as long as the span (Figure F-1). We made separate estimates of each cell for different periods of time corresponding to different heights of vegetation. For CTB, we made only a visual estimate of the entire transect.

The habitat expansion factor was also used to compensate for the reduced search width in the hay field. An analysis of the distribution of dead birds in Year 1 as a function of the distance from the center conductor in the hay field provided a best fit to an exponential model. Based on the fitted model, 67% of the birds would be expected to be within 8 m north of the center conductor. Thus, an estimate of the number of birds found within the full transect width was determined by setting the proportion of searchable area to .67 in cell C for Years 2 and 3 (Appendix F).

Calculation of Estimates

Following the methods presented by Faanes (1987), we calculated the estimated total dead birds and the estimated collisions as follows:

$$EDB = 1 + SB + SR + HF$$

$$EC = EDB/(1 - CB)$$

where

EDB = estimated dead birds derived from one collected bird

EC = estimated collisions

SB = search bias

SR = scavenger removal

HF = habitat expansion factor

CB = crippling bias (0.74).

A separate EDB was calculated for the corresponding mean and lower and upper limits of the search bias 90 percent confidence interval. Note that the resulting range of EDB values do not represent a 90% confidence interval about the mean EDB. A true 90% confidence interval would be larger because it would incorporate variation in scavenger and habitat biases.

EDB and EC were then summed separately for each of the birds collected within each transect and year of the study to yield estimated total dead birds (ETDB), and estimated total collisions, respectively. We compared estimates between transects after standardizing by time (weeks) and area (ha).

EFFECTS OF WEATHER AND LOCAL BIRD POPULATION SIZE ON BIRD MORTALITY

We investigated the relation between weather and the amount of bird mortality to understand how environmental factors contribute to birds' susceptibility to collisions with powerlines. Our focus was to determine if factors that are suspected of contributing to bird mortality at structures (e.g., low visibility, moon phase, high winds, and precipitation) contributed significantly to the variation in mortality seen in this study. Ultimately, an understanding of how weather conditions influence bird mortality at structures will aid in designing and evaluating potential mitigation measures.

The methods used to analyze the relation between weather variables and bird mortalities are outlined below. They are discussed fully in Appendix G.

Weather Data Collection

Weather data were collected at two locations. At the study site data were collected daily during periods in which dead bird searches were conducted. Weather data were also obtained from a private weather station located near Slaughterhouse Point on the Napa River, approximately 8 km east of the site. Data included measures of air temperature, wind speed and direction, visibility, height of cloud cover, precipitation, and general weather conditions.

Weather Data Analysis

We analyzed the relation between the amount of bird mortality and weather using stepwise multiple regression, a type of multivariate statistical analysis. Multiple regression is used to investigate relations between a continuously varying dependent variable (in this study, bird mortality) and a number of interrelated independent, or predictor, variables (weather variables).

The number of birds in the vicinity of the powerline would be expected to have a strong effect on the amount of mortality. Monthly surveys of the number of birds crossing the line and the number present on Leslie Pond 1 were available from late October 1989 through early May 1991. (The next section describes these surveys.) Survey results were used as estimates of local bird density. Since these results were only available for the second and third years of the study, analysis was limited to Year 2 and Year 3.

Since birds differ in their seasonal presence at the study site and in their behavior, we would expect the effect of weather on mortality to vary among major bird groups. In previous years all bird species were combined for the weather analysis, since subdividing would result in small sample sizes. For this report three major groups were analyzed: wintering "ducks," shorebirds, and "landbirds." The species included in each group are listed in Table G-2. Wintering "ducks" included coots, grebes, and most ducks other than cormorants. Shorebirds included most species other than avocets, stilts, and yellowlegs, none of which experienced mortality during this study. "Landbirds" is a generalized group consisting of passerines, hummingbirds, doves, and other small terrestrial species.

In previous years, we analyzed three models: 1) a weekly model, which included mortality for 2 days of searches in the week and weather variables representing the average weather for the preceding week, 2) a "Day 2 Model," which included mortality from the second day of each 2 day search period, and weather for that morning and the preceding day, and 3) a "Day 1 Model", which included similar data for the first day of each search period. As might be expected, the second data set (Day 2) gave the most consistently interpretable results. Only the Day 2 model is analyzed here.

FLIGHT PATTERN STUDY

Daytime Surveys

From October through May in Year 2 and August through May in Year 3, two qualified observers surveyed bird flights on three consecutive days per month. Beginning within 15 minutes of sunrise, each observer recorded bird flight information for 1 hour at each of three locations (six locations in all). Observers repeated the survey in the afternoon and finished surveying the last site within 15 minutes of sunset. Bird flight characteristics including species, altitude, reaction, direction, flock size, and time were recorded for each flock seen crossing the transect (Appendix H). Survey transects consisted of two spans (or equivalent distance in CTB).

Observers surveyed each flight pattern transect from pole 1 in Year 2 (for CTA), poles 6, 10, and 14 in Year 2 and poles 6, 8, 12, and 14 in Year 3 (for the salt pond transect) while looking north for two spans, pole 44 in Year 2 and pole 24 in Year 3 (hay field transect) looking west for two spans, and at 500 m south of the Vaca-Ignacio transmission line in CTB looking north for 250 m (delineated with markers spaced at 50 m intervals). The survey locations in the salt pond transect were moved from the previous year to coincide with the design of the proposed power line marker study; therefore, in Year 3 no survey was done of CTA. The hay field survey was moved to pole 24 to reduce the bias created by the many birds roosting in a large Eucalyptus tree at pole 44.

Night Surveys

Night surveys were conducted at the same four locations along the salt pond transect as the day surveys. In Year 2 surveys were conducted on three consecutive nights and the sampling period was from within 15 minutes after sunset to 0030-0230 h. The survey was resumed from 0430 h to within 15 minutes of sunrise. Night observations were conducted on two consecutive nights in Year 3 and began approximately one-half hour past sunset and were continuous until approximately one-half hour before sunrise. Observations were made through a night-viewing device coupled with a 500-mm light gathering lens. Observers recorded the same flight characteristics as for the day observations.

Section 4

RESULTS

BIRD MORTALITY MONITORING

Numbers and Species of Birds Found

In all transects during Years 1-3, we found the remains of 1,028 birds representing at least 86 species (we were able to identify 90% of the remains to species) (Tables 4-1 through 4-4, Figures 4-1 through 4-4). With the exception of CTB, we found fewer birds in each successive year. The species we found most often were ruddy duck, black-bellied plover, western sandpiper, dunlin, savannah sparrow, and western meadowlark. The remains that represent these species accounted for 56% of all the specimens. In Year 3, of the 214 specimens collected, we identified 200 (92%) to species. The specimens that could not be identified to species were given as specific a classification as possible (e.g. shorebird species). Two black rails were found in Year 2 and one black rail was found in Year 3. The black rail is listed as California Threatened. No federally listed threatened or endangered species were found.

In the hay field transect, the number of birds recovered declined each year. Red-winged blackbirds and western meadowlarks each show a significant reduction in numbers recovered. With other species in the hayfield, the recoveries were too few to show meaningful trends. The 152 birds found in the hay field were predominantly passerines (77%).

The number of birds found in the salt pond transect was much more consistent from year to year, especially if the 33 ruddy ducks killed from the cholera outbreak in February, 1989, are removed from the Year 1 totals. We found 633 birds over three years. There was a large decline in the number of ruddy ducks recovered each successive year, and the number of western sandpipers also declined. Species that showed a conspicuous, steady increase in recoveries each year were black-bellied plovers, dunlins, and savannah sparrows. Non-passerines represent 83% of the species found in the salt pond transect, and of those, 56% were shorebirds.

In CTA, we found the remains of 80 birds over three years. Recoveries declined each year, although the number of passerines remained relatively steady. Other than the overall reduction in numbers, there are no noteworthy trends in CTA. Shorebirds made up 46% of the total mortality.

As mentioned above, CTB was the only transect having an increase in the number of birds found. More specimens were recovered in Year 3 than in Year 2, but Year 1 still had far more recoveries--largely due to a high number of ducks. The number of shorebirds recovered, especially dunlins, increased markedly in Year 3. Still, after three years, 46% of the 162 birds found were ducks.

Table 4-1. Hay field mortality: Number of specimens collected in the hayfield transect per season by species and month.

Month	Jul[1]			Aug			Sep			Oct			Nov			Dec			Jan			Feb			Mar			Apr			May			Total			
Season	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	Total
Species																																					
Double-crested cormorant	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	2
Mallard	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	1	.	.	1
Cinnamon teal	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
Greater scaup	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
Lesser scaup	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	1	1
Ruddy duck	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1	1	.	2
California quail	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1
Black rail	.	1	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	2
Sora	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
Black-bellied plover	.	.	.	1	.	1	2	.	.	2	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	1	.	.	.	.	5	1	2	8
Western sandpiper	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	2	.	.	1	.	.	.	.	.	.	.	.	.	1	1	.	.	1	5	1	7
Dunlin	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	2
Rock dove	.	.	.	.	.	1	.	.	1	.	1	1	1	.	.	1	.	.	.	.	2	3	.	1	.	.	.	.	.	.	.	.	.	5	1	6	12
Mourning dove	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	1
Western flycatcher	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	1	.	2
House wren	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1
Ruby-crowned kinglet	.	.	.	.	.	.	.	.	.	1	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	2	3
Hermit thrush	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	1
American pipit	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	2
European starling	.	.	.	.	1	.	.	.	.	.	.	1	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	1	4
Townsend's warbler	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	1
Wilson's warbler	.	.	.	.	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	1	2	3
Chipping sparrow	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
Savannah sparrow	.	.	.	.	.	.	3	3	1	1	2	2	1	2	1	1	1	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	6	9	4	19
Lincoln's sparrow	.	.	.	.	.	.	1	.	.	.	1	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	1	.	3
Golden-crowned sparrow	.	.	.	.	.	.	.	.	1	.	1	1	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	1	3	4
White-crowned sparrow	.	.	.	.	.	.	.	1	.	.	3	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	4	1	6
G. or W.-crowned sparrow	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1
Sparrow species	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	2
Dark-eyed junco	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
Red-winged blackbird	.	.	.	1	.	.	1	.	.	.	1	.	2	1	.	2	.	.	1	.	.	4	.	.	1	.	.	.	2	.	2	1	1	14	5	1	20
Western meadowlark	.	.	.	.	.	.	.	.	.	2	3	.	1	3	1	4	1	.	4	.	.	2	.	.	.	.	.	.	.	.	.	.	.	13	7	1	21
Brewer's blackbird	.	.	.	.	.	.	.	.	.	.	2	.	.	.	1	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	3	2	1	6
House finch	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	3
Bird species	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	1	.	.	.	.	.	.	.	.	1	.	.	2	.	.	6	.	.	6
Hoary bat	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1
Total	N/A	1	0	2	3	4	8	7	3	8	19	7	8	8	5	14	8	0	8	3	4	10	0	1	1	1	0	2	3	3	7	1	4	68	54	31	153

[1]To allow monthly comparisons between seasons, "analysis" months were developed with the same number of search days for the same month in different seasons.

Table 4-2. Salt pond mortality: Number of birds collected in the salt pond transect per season by species and month.

Month	Jul			Aug			Sep			Oct			Nov			Dec			Jan			Feb			Mar			Apr			May			Total			
Season	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	Total
Species																																					
Red-throated loon	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1
Grebe species	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1
Pied-billed grebe	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	1	1
Horned grebe	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1
Eared grebe	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1	1	.	2
Western grebe	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1
Double-crested cormorant	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	2
Brandt's cormorant	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
Green-winged teal	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
Duck species	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	1	1	.	.	.	.	.	.	.	1	.	.	.	.	.	3	1	4
Northern pintail	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	1	.	1
Cinnamon teal	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	1
Gadwall	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	2	1	.	3
American wigeon	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	2
Canvasback	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	2
Greater scaup	.	1	.	.	.	.	.	1	.	3	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	5	2	.	7
Lesser scaup	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1
Scaup species	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	3	1	.	4
Bufflehead	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	2	1	.	3
Ruddy duck	.	.	.	.	1	1	.	1	.	1	.	.	5	2	.	5	5	1	18	9	2	59	1	.	13	6	.	4	.	.	2	1	.	107	26	4	137
Black-shouldered kite	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
Black rail	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1
Virginia rail	.	.	.	.	.	1	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	2
Sora	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	3
American coot	.	.	.	.	.	.	.	1	.	.	2	.	.	1	4	1	1	.	.	3	2	4	3	1	1	1	.	.	.	1	.	.	.	6	12	8	26
Black-bellied plover	.	2	1	6	10	10	9	7	11	.	3	9	.	3	5	1	4	1	.	.	.	3	1	.	.	2	.	.	.	.	.	.	.	19	32	37	88
Semipalmated plover	.	.	1	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	3
Killdeer	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1
Willet	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	2
Wandering tattler	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1
Long-billed curlew	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1
Marbled godwit	.	2	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	1	5
Ruddy turnstone	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
Sanderling	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	1
Western sandpiper	.	1	3	2	1	3	4	3	1	1	2	2	.	2	4	3	2	2	.	.	1	1	1	.	1	1	.	8	.	1	6	8	1	26	21	18	65
Least sandpiper	.	.	.	.	1	.	1	1	1	.	.	.	.	.	.	.	1	1	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	1	3	4	8
Sandpiper species	.	.	.	1	.	.	2	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	3	.	6
Peep species	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1
Dunlin	.	.	.	.	.	1	.	.	1	1	1	5	4	3	23	1	11	6	.	4	1	.	.	.	.	.	.	.	.	.	.	4	.	6	23	37	66
Short-billed dowitcher	.	.	.	.	3	3	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	4	7
Long-billed dowitcher	.	.	.	.	.	.	.	.	.	1	.	.	.	.	3	.	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1	.	5	6
Dowitcher species	.	.	.	.	.	.	.	1	.	.	.	.	1	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	2	4
Shorebird species	.	.	.	.	.	1	.	.	2	.	.	.	.	1	3	.	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	1	8	9
Red-necked phalarope	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	1	.	1	3	1	1	5
Bonaparte's gull	.	.	.	1	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	1	1	3
Mew gull	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
Ring-billed gull	.	1	.	.	.	1	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	1	4
California gull	.	.	.	.	2	1	1	1	3	.	.	3	.	.	3	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1	3	11	15
Herring gull	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1

4-3

Table 4-2. (continued)

Month	Jul			Aug			Sep			Oct			Nov			Dec			Jan			Feb			Mar			Apr			May			Total			
Season	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	Total
Species																																					
Western gull	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1
Gull species	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	2
West.XGl.-winged gull	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1
Tern species	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
Caspian tern	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
Rock dove	.	.	.	1	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	2
Common barn owl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1
Short-eared owl	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1
Black phoebe	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1
Ruby-crowned kinglet	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
Hermit thrush	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1
Varied thrush	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1
American pipit	.	.	.	.	.	.	.	.	.	2	.	.	1	.	.	.	.	.	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	4	1	1	6
European starling	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1
Warbler species	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	1
Orange-crowned warbler	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	1	.	1
Yellow warbler	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1
Wilson's warbler	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
Rufous-sided towhee	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
Chipping sparrow	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
Savannah sparrow	.	.	.	.	.	.	.	2	1	.	1	1	1	1	.	.	.	2	.	.	.	.	.	3	.	1	3	.	3	4	.	.	.	1	8	14	23
Song sparrow	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
Lincoln's sparrow	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
White-crowned sparrow	.	.	.	.	.	.	1	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	2	2	.	4
Sparrow species	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	1	.	1
Red-winged blackbird	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	1	.	.	.	.	1	3	.	4
Western meadowlark	.	.	.	.	.	.	1	.	.	1	2	1	.	3	.	.	2	1	1	.	.	.	.	.	1	2	.	1	.	1	1	.	.	6	9	3	18
Purple finch	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
House finch	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	3	1	.	1	.	.	1	.	.	1	.	.	1	.	.	8	1	9
Finch species	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
Passerine species	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	2	.	2
Bird species	.	.	.	1	.	.	4	.	.	.	2	1	1	1	.	3	.	.	5	1	.	5	.	.	2	1	.	.	1	.	.	.	.	21	6	1	28
Total	N/A	7	7	15	25	23	25	26	23	16	16	26	19	27	52	15	31	19	26	25	13	78	9	6	20	18	3	15	9	9	13	15	2	242	208	183	633

Table 4-3. Comparison transect A mortality: Number of birds collected in comparison transect A per season by species, month, and season.

Month	Jul			Aug			Sep			Oct			Nov			Dec			Jan			Feb			Mar			Apr			May			Total			
Season	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	Total
Species																																					
American white pelican	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	2
Double-crested cormorant	.	.	.	.	.	.	.	1	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	1	.	3
Great blue heron	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	2
Mallard	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1
Common goldeneye	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1
Bufflehead	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1
Ruddy duck	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	1	3	1	.	.	.	.	1	.	.	.	.	.	5	3	1	9
American kestrel	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1
American coot	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1
Black-bellied plover	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	2	1	3
Western sandpiper	.	3	.	.	2	1	.	.	4	.	1	.	.	.	2	.	.	.	1	.	.	.	.	.	.	.	.	1	.	.	3	.	.	5	6	7	18
Least sandpiper	.	.	.	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	2	1	3
Sandpiper species	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1
Peep species	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
Dunlin	.	.	.	.	.	.	.	.	.	.	3	.	3	.	2	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	3	3	9
Short-billed dowitcher	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	1
Dowitcher species	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
California gull	.	.	.	.	1	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	2
Gull species	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
American pipit	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1
Savannah sparrow	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	2	2
Golden-crowned sparrow	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1	1	2
Red-winged blackbird	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
Western meadowlark	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	.	.	1	.	.	1	.	.	.	.	1	.	.	.	1	.	.	3	2	1	6
House finch	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1	1
Bird species	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	1	.	.	.	.	.	.	.	.	1	.	.	1	.	.	.	.	.	6	.	.	6
Total	N/A	4	0	N/A	6	1	N/A	2	5	N/A	5	0	17	2	6	3	2	3	2	0	2	4	2	2	1	0	1	3	0	0	4	3	0	34	26	20	80

Table 4-4. Comparison transect B mortality: Number of birds collected in comparison transect B by species, month, and season.

Month	Aug			Sep			Oct			Nov			Dec			Jan			Feb			Mar			Apr			May			Total			
Season	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	88-/89	89-/90	90-/91	Total
Species																																		
Red-throated loon	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1
Pied-billed grebe	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
Double-crested cormorant	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	2	.	2
Great egret	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1
Snowy egret	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
Black-crowned night heron	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	3
Green-winged teal	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	2	2
Northern pintail	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1
Northern shoveler	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	1	.	.	2	.	2
Gadwall	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1
American wigeon	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	2	.	.	.	.	.	.	.	.	.	.	.	3	.	.	3
Canvasback	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1	.	2	1	1	.	.	.	.	.	.	.	.	.	.	.	1	3	2	6
Redhead	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
Greater scaup	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	2	.	1	.	.	2	.	.	.	.	.	.	.	.	8	2	.	10
Lesser scaup	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	2	.	.	2
Scaup species	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	3	1	.	1	.	.	.	.	.	.	.	.	5	1	.	6
Ruddy duck	.	.	.	.	.	.	.	.	.	.	1	1	.	2	2	5	.	1	5	3	1	12	2	.	6	.	.	.	.	.	28	8	5	41
Peregrine falcon	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1	1
American coot	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	3	.	.	6	.	.	.	.	.	.	.	.	.	.	.	9	1	1	11
Black-bellied plover	.	.	.	.	.	.	.	1	3	.	.	1	.	.	.	1	.	1	1	1	.	.	.	.	.	.	.	.	.	.	2	2	5	9
Black-necked stilt	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1
American avocet	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	1	.	1	.	.	.	.	.	.	2	.	2	4
Western sandpiper	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	1	2
Least sandpiper	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	1	.	.	.	.	.	1	2	3
Dunlin	.	.	.	.	.	.	.	.	1	.	.	3	.	.	5	.	.	2	.	.	3	.	.	.	.	.	1	.	.	.	.	.	15	15
Dowitcher species	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	2
Shorebird species	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1	.	1
Ring-billed gull	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
Rock dove	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	2	1	.	3
Western bluebird	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	1	.	.	1
Savannah sparrow	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	1	1	2
White-crowned sparrow	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
Red-winged blackbird	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	1	1	2
Western meadowlark	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	1	.	.	.	1	.	1	.	.	.	.	.	.	.	.	2	1	1	4
House finch	.	.	.	.	.	.	.	.	.	.	1	.	.	2	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	4	1	5
Passerine species	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
Bird species	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	4	.	.	1	.	.	1	.	.	2	.	.	.	.	.	8	.	1	9
Total	N/A	N/A	1	N/A	4	0	N/A	3	6	N/A	2	6	N/A	7	12	27	5	11	23	10	7	21	2	1	8	3	1	0	2	0	79	38	45	162

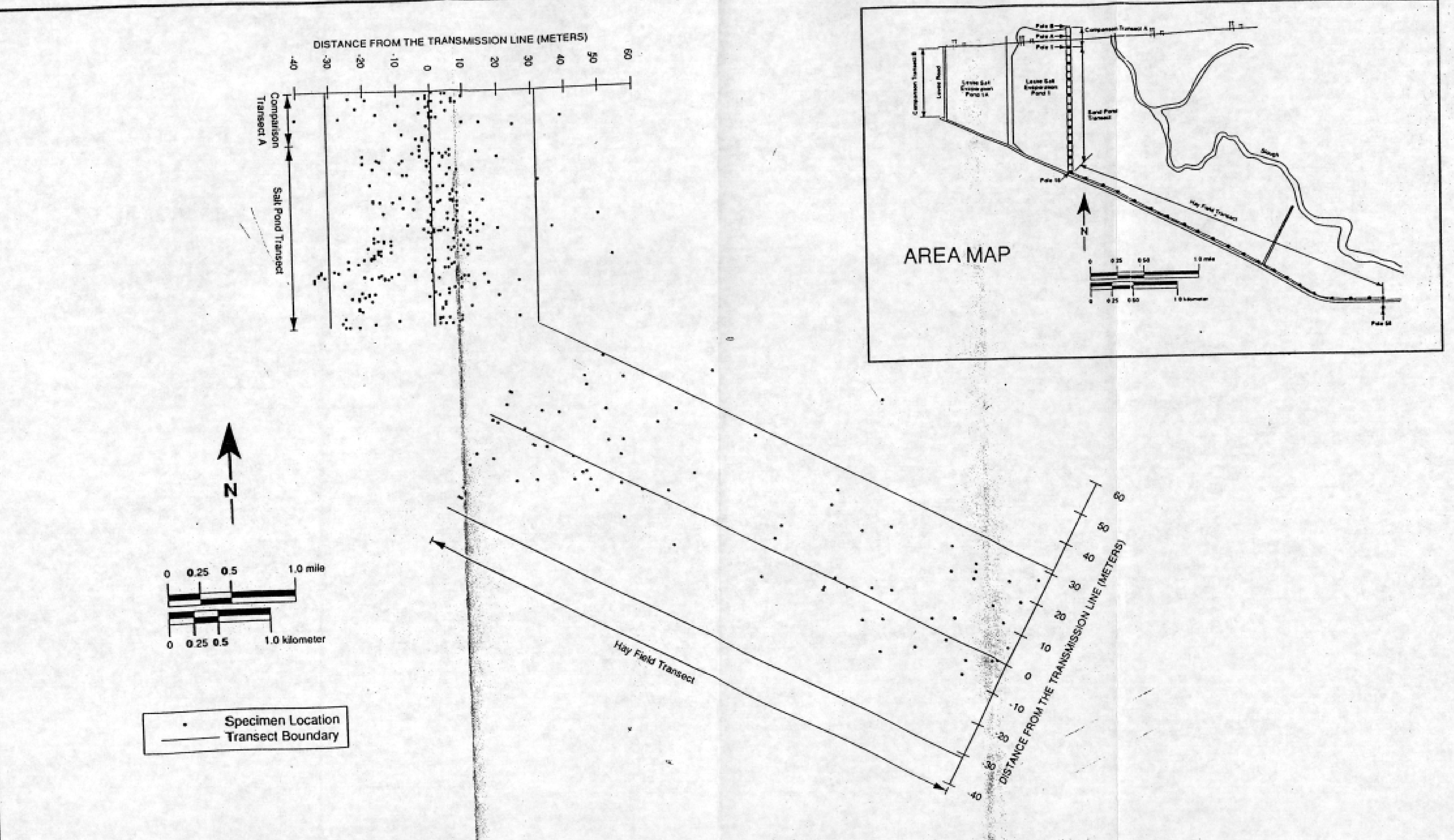


Figure 4-1. Locations of specimens found in the hay field and salt pond transects, and comparison transect A in Year

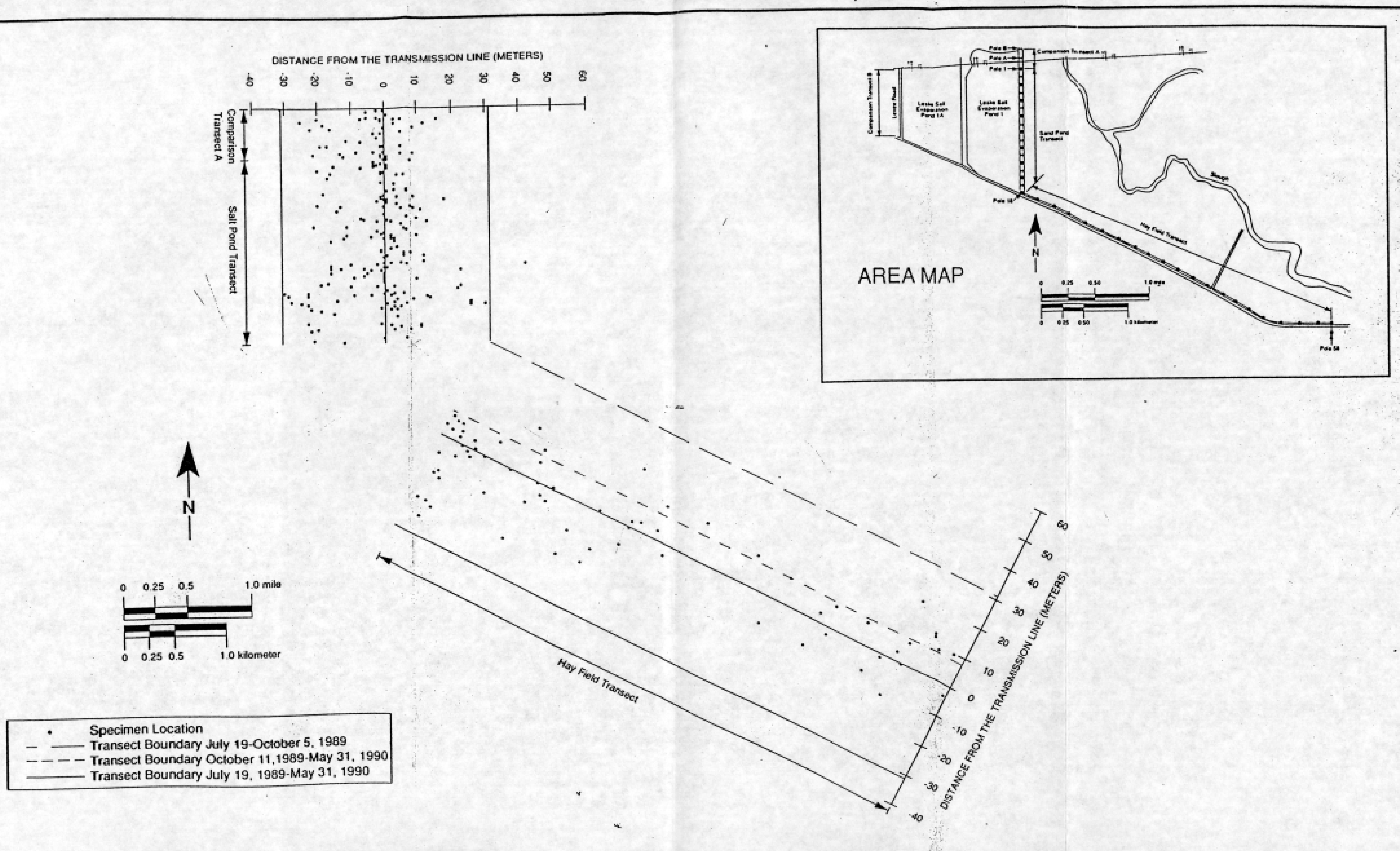


Figure 4-2. Locations of specimens found in the hay field and salt pond transects, and comparison transect A in Year 2.

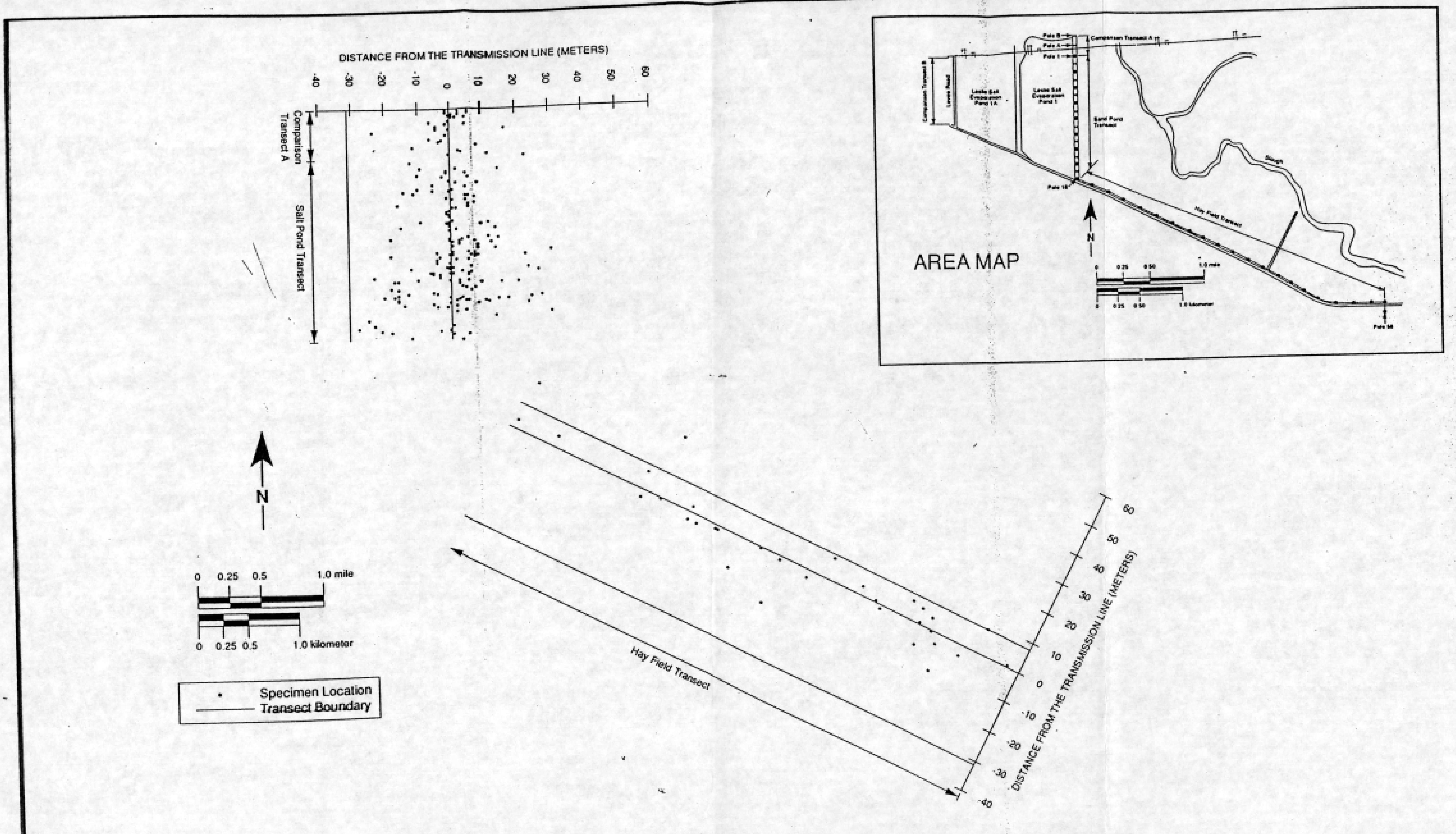


Figure 4-3. Locations of specimens found in the hay field and salt pond transects, and comparison transect A in Year 3.

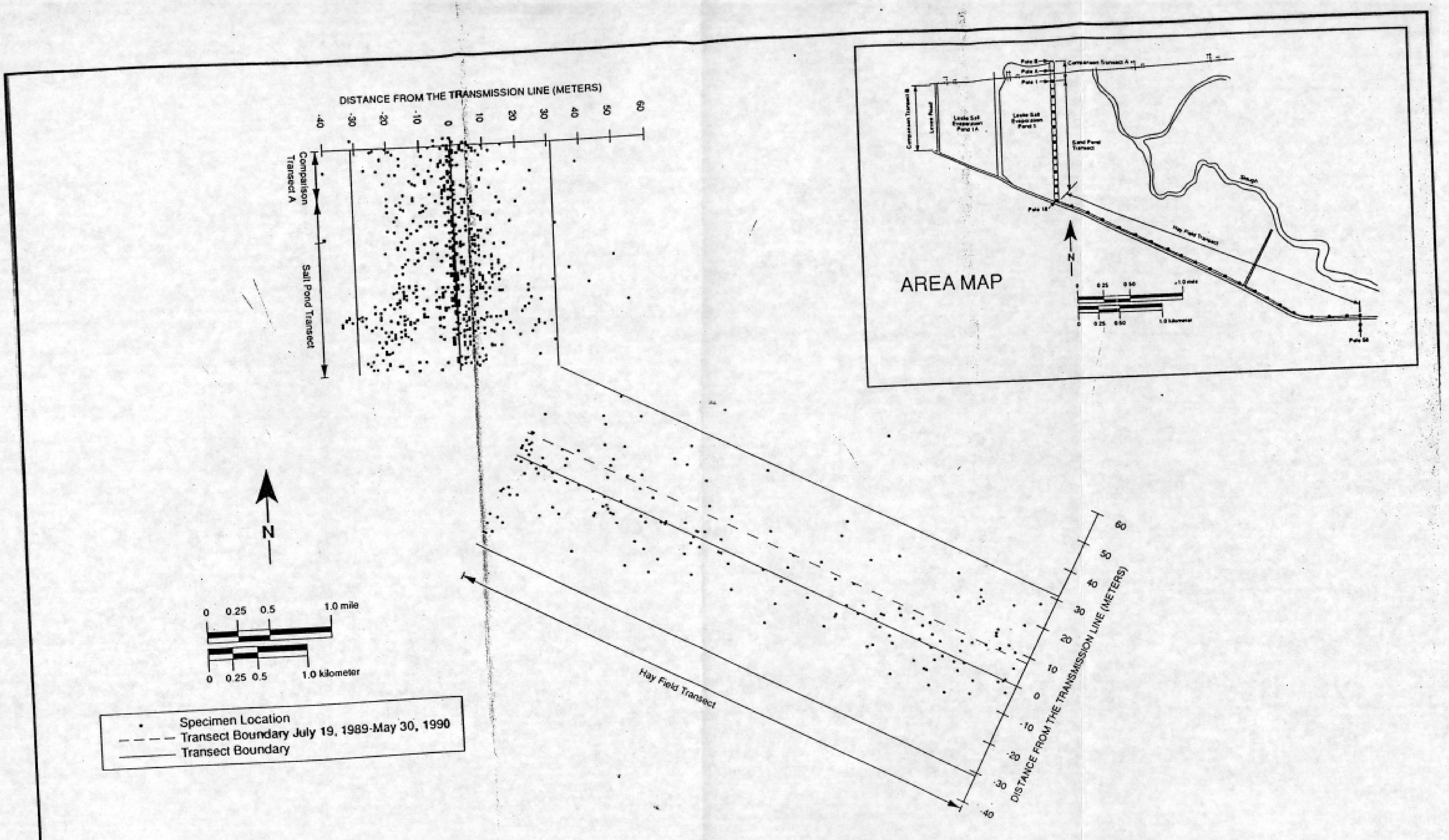


Figure 4-4. Locations of specimens found in the hay field and salt pond transects, and comparison transect A in Years 1-3.

Cause of Death

Of 154 birds from the hay field and salt pond transects submitted for necropsy, the cause of death could be determined for 108 birds (Appendix C). These figures do not include 27 ruddy ducks from the salt pond not submitted for necropsy that we assumed died in a large cholera epidemic in Year 1. An additional 13 injured birds were found over three years in the hay field and salt pond transects. These birds were suffering from obvious trauma injuries--primarily with wings severed or broken. We assumed these birds would have died from their injuries. The categories for cause of death from the hay field and salt pond transects include: cholera, gunshot wounds, malnutrition, trauma, suspected trauma, and unknown.

Far fewer birds were necropsied in Years 2 and 3 than in Year 1. After the first year we limited the carcasses brought in for necropsy to those in fairly good condition. With the exception of one golden-crowned sparrow, cholera as a cause of known mortality was limited to Year 1. Trauma or suspected trauma was the cause of death for 106 of 115 (92%) birds with known cause of death from the hay field and salt pond transects (including live, injured birds and excluding the 33 ruddy ducks found during the Year 1 cholera epidemic).

MORTALITY AND COLLISION ESTIMATES

Search Bias

Using the results of tests 3-9, we estimate a recovery rate of 20% for detection class 2 birds and 90% for detection class 3 (Table 4-5). Detection class 4 birds must by definition attract the searchers' attention, so their recovery rate is 100%. Although we planted and later relocated 25 detection class 1 birds during our tests, none of them were found by searchers. We will continue to assume a 5% recovery rate for detection class 1 birds.

Search Bias Test 9, the only test conducted in Year 3, was an attempt to more accurately estimate the recovery percentage of specimens which are difficult to detect (detection classes 1 and 2). None of the 25 planted specimens were found by the searchers; however, five of them could not be relocated at the conclusion of the test (Appendix D). Actual specimens may persist for more than one day before searchers find them. We were unable to conduct a test that allowed test specimens to remain for an extended period for several reasons: 1. searchers might suspect that they are being tested when planted feathers are marked for later identification, and 2. the specimens could disappear without our knowledge. We only conducted one test in Year 3 because we are confidant in our recovery estimates for Detection Class 3 and 4 specimens, and a more accurate estimate of Class 1 and 2 specimens probably depends on a test allowing for persistence.

Table 4-5. Search Bias Tests: Number and percent of birds recovered by searchers in each detectability class during search bias tests 3-9.

	Detectability Level			
Test	1	2	3	4
3	0/5[1]	1/5	N/A	N/A
4	N/A	2/4	10/10	N/A
5	0/1	1/2	4/5	N/A
6	0/2	0/1	4/5	N/A
7	N/A	0/5	6/7	N/A
8	N/A	1/5	4/4	1/1
9	0/17	0/3	N/A	N/A
Percent Recovered	0%	20%	90%	100%

[1]Represents number of birds recovered by searchers out of birds recovered either by searchers or by tester at the conclusion of the study.

Scavenger Removal Bias

Scavenging rates were quite variable between transects, months, and years, so few trends stand out (Appendix E). Also, in Year 1 fewer scavenger studies were conducted and two were of shorter duration, resulting in an incomplete portrayal of Year 1 scavenging rates. The least amount of overall scavenging seems to have occurred in Year 2. In Years 1 and 3 the least amount of scavenging occurred in late spring. Since scavenging rates varied, we continued calculating scavenging bias separately for each specimen recovered by applying the appropriate rate based on location, date, and time interval between search days.

Habitat Bias

In the hay field transect, the poor searchability of the ditch and road bank between Highway 37 and the hay field is reflected by the low proportions of area that can be searched for Cell A (Appendix F). The narrowed northern half of the transect is likewise reflected by the searchability figures for Cells C and D. Timing of manual vegetation control in the hay field was much better in Years 2 and 3.

The application of herbicides along with manual control, in addition to improved timing of control measures, combined to give much better searchability in Year 2. Lack of rain kept the vegetation down in Year 3. Consequently, all cells were searchable until late March, when the vegetation reduced search effectiveness. At that point our efforts to control vegetation were somewhat limited due to birds nesting in the transect. The manual vegetation reduction in mid-May, as well as the hay harvest in late May, is reflected in the increased searchability of the respective cells.

In Year 1, 80% of CTB was searchable until March, when high vegetation left only 40% of the transect searchable. Manual vegetation control in Year 2 kept the transect 80% searchable the entire year. Weed control was not necessary in Year 3. High pickleweed on the western edge of the transect left 90% of the area searchable.

Calculation of Estimates

In each of the three years of the study, the estimated total dead birds in the hay field transect have remained consistently lower than those in the salt pond transect (Figure 4-5 and Table 4-6). The greatest difference in estimated dead birds between these transects was in Year 3. From all three years, the estimated total dead birds found per hectare in the salt pond transect was about nine times that found in the hay field transect (Table 4-7). The estimated dead birds per hectare per week in CTA was only slightly more than the salt pond transect estimate, but the standardized CTB estimate was more than three times larger than the salt pond estimate (Table 4-7).

Compared with other bird mortality studies, the standardized estimates from the hay field and salt pond transects are lower and higher, respectively, than the estimates calculated by others (Table 4-7).

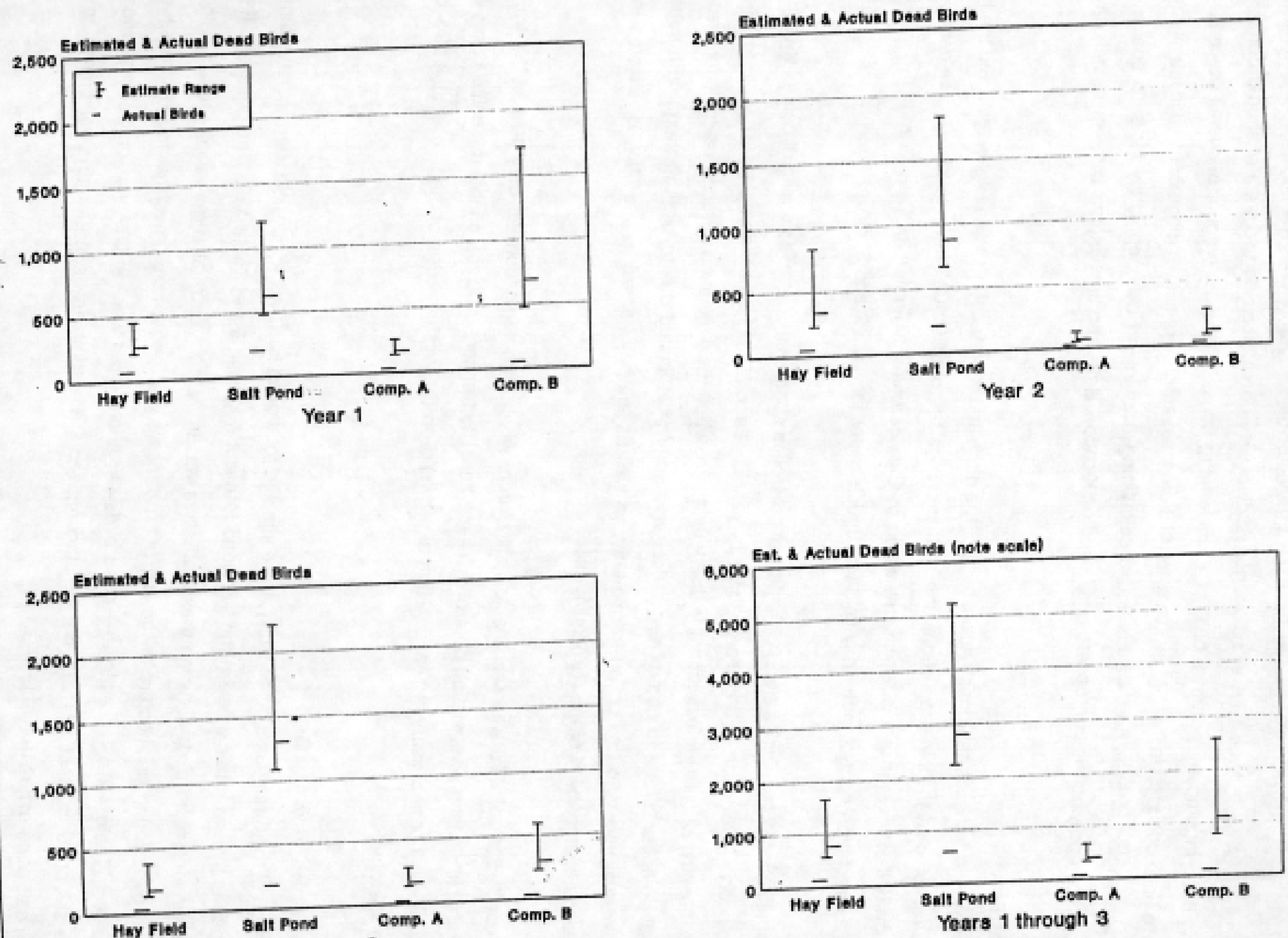


Figure 4-5. Actual and estimated dead birds. See text for explanation of range.

Table 4-6. Dead birds found, estimated dead birds, and estimated collisions. Except for "dead birds found," values in the L and H columns represent the lower and upper limits, respectively, of the search bias 90% confidence interval.

	Year 1			Year 2			Year 3			Years 1-3		
	L	M	H	L	M	H	L	M	H	L	M	H
Hay Field Transect												
Dead birds found	67			48			28			143		
Search bias	63	94	212	34	71	239	14	30	101	111	195	552
Scavenger bias	74	90	151	45	63	142	62	82	170	181	235	463
Habitat bias	4	7	20	101	154	406	26	36	82	131	197	508
Estimated dead birds	208	258	450	229	335	836	130	176	381	567	769	1,667
Estimated collisions	799	991	1,731	881	1,290	3,214	499	679	1,466	2,179	2,960	6,411
Salt Pond Transect												
Dead birds found	204			206			184			594		
Search bias	121	219	610	240	378	1,013	121	211	605	482	808	2,228
Scavenger bias	138	177	322	207	268	542	785	912	1,420	1,130	1,357	2,284
Habitat bias	19	28	69	17	26	71	1	2	3	37	56	143
Estimated dead birds	482	627	1,204	670	878	1,832	1,091	1,308	2,212	2,243	2,813	5,248
Estimated collisions	1,856	2,413	4,633	2,576	3,376	7,046	4,197	5,033	8,507	8,629	10,822	20,186
Comparison Transect A												
Dead birds found	34			26			20			80		
Search bias	42	55	100	10	22	73	12	25	85	64	102	258
Scavenger bias	51	62	98	14	17	29	97	112	157	162	191	284
Habitat bias	12	14	22	2	3	4	8	10	17	22	27	43
Estimated dead birds	140	165	254	53	68	132	137	167	279	330	400	665
Estimated collisions	539	634	977	203	262	506	527	644	1,072	1,269	1,540	2,555
Comparison Transect B												
Dead birds found	53			30			34			117		
Search bias	66	117	355	22	46	155	10	23	75	98	186	585
Scavenger bias	150	216	522	14	19	40	161	211	425	325	446	987
Habitat bias	202	304	783	17	24	56	23	30	59	242	358	898
Estimated dead birds	471	691	1,712	83	119	281	228	298	593	782	1,108	2,586
Estimated collisions	1,812	2,656	6,586	321	458	1,081	876	1,147	2,281	3,009	4,261	9,948

Table 4-7. Dead birds found (DBF), estimated total dead birds (ETDB), and estimated total collisions (ETC) from Years 1-3. Counts and estimates were also standardized by area and sampling period to permit comparison between studies.

					Faanes (1987)				James & Haak (1979)
	Hay Field	Salt Pond	Comparison Transect A	Comparison Transect B	Cherry Lake	Kunkel Lake	Sibley Lake	Heijnis 1976	Lower Crab Creek
Transect length (m)	4717	1900	244	900	1990	1100	1800	3300	700
Transect width (m)	61	61	61	20	90	90	90	150	100
Transect area (ha)	28.8	11.6	1.5	1.8	17.9	9.9	16.2	49.5	7.0
Sample Period (wks)	136	136	121	101	52	52	52	150	16
Dead birds found	143	594	80	117	129	164	205	2280	25
Search bias	195	808	102	186	N/A	N/A	N/A	N/A	N/A
Scavenger bias	235	1356	192	446	N/A	N/A	N/A	N/A	N/A
Habitat bias	196	55	26	358	N/A	N/A	N/A	N/A	N/A
ETDB	769	2813	400	1107	388	353	297	4947	135
ETC	2958	10819	1538	4258	1488	1357	1142	6000	540
DBF per ha	5	51	54	65	7	17	13	46	4
ETDB per ha	27	243	269	615	22	36	18	100	19
ETC per ha	103	933	1034	2365	83	137	70	121	77
DBF per ha/wk	.04	.38	.44	.64	.14	.32	.24	.31	.22
ETDB per ha/wk	.20	1.78	2.22	6.09	.42	.69	.35	.67	1.21
ETC per ha/wk	.76	6.86	8.54	N/A	1.60	2.64	1.36	.81	4.82

EFFECTS OF WEATHER AND LOCAL BIRD POPULATION SIZE ON BIRD MORTALITY

Results of the multiple regression analysis of weather variables and bird density on bird mortality are presented in detail in Appendix G. Year 1 data were not used in final weather analysis because corresponding information on local bird population density needed for the multiple regression analysis was not available for Year 1. The variation in bird mortality explained by the multiple regression model varied from 16% to 65% (multiple R^2) when data for Year 2 and Year 3 were modeled separately. When data for Year 2 and Year 3 were combined, the proportion of variation explained by the model was 18% for ducks, 20% for shorebirds, and 25% for landbirds. Tidal variation explained some of the variation in mortality, but this variation was not readily interpretable. All regressions were statistically significant ($p < .05$).

The reduction in the amount of variation explained when Year 2 and Year 3 duck group data are combined suggests that different weather factors were affecting mortality in Year 2 as compared to Year 3. For the Year 2 and Combined Year models, mortality decreased as the east-west component of the preceding day's wind increased. Duck group population size in the local area was a very weak predictor of mortality.

No clear or consistent relationships were found between bird mortality and weather or local area shorebird populations when Year 2 and Year 3 data were analyzed separately. When Year 2 and Year 3 data were combined, shorebird population size in the local area was the only variable which provided information on predicting mortality.

For landbirds, local area population size was a weak predictor of mortality. The positive relation between maximum wind speed on the preceding day and landbird mortality is the strongest and most consistent relation of a weather variable with mortality.

FLIGHT PATTERN STUDY

Day Studies

Flights per Month. The overall number of flights in both Years 2 and 3 peaked in the fall (Figures 4-6 and 4-7). In Year 3, flight numbers peaked during November for all transects studied. Although morning flights generally outnumbered afternoon flights in Year 2, no such trend was evident in Year 3. The relocation of the hay field site away from the eucalyptus tree is reflected in the reduction of passerine flights in the hay field during Year 3. The number of non-passerine flights in the hay field decreased significantly as well in Year 3.

Altitudes of Birds Crossing Powerlines. Altitudes recorded during flight pattern studies are illustrated in Figure 4-8. The majority of birds crossed the powerlines at altitudes 6, 7, or 8 (Figures 4-9 and 4-10). Flight altitude 6, considered at-risk, represents 42% of the non-passerine flights in the salt pond over the two years.

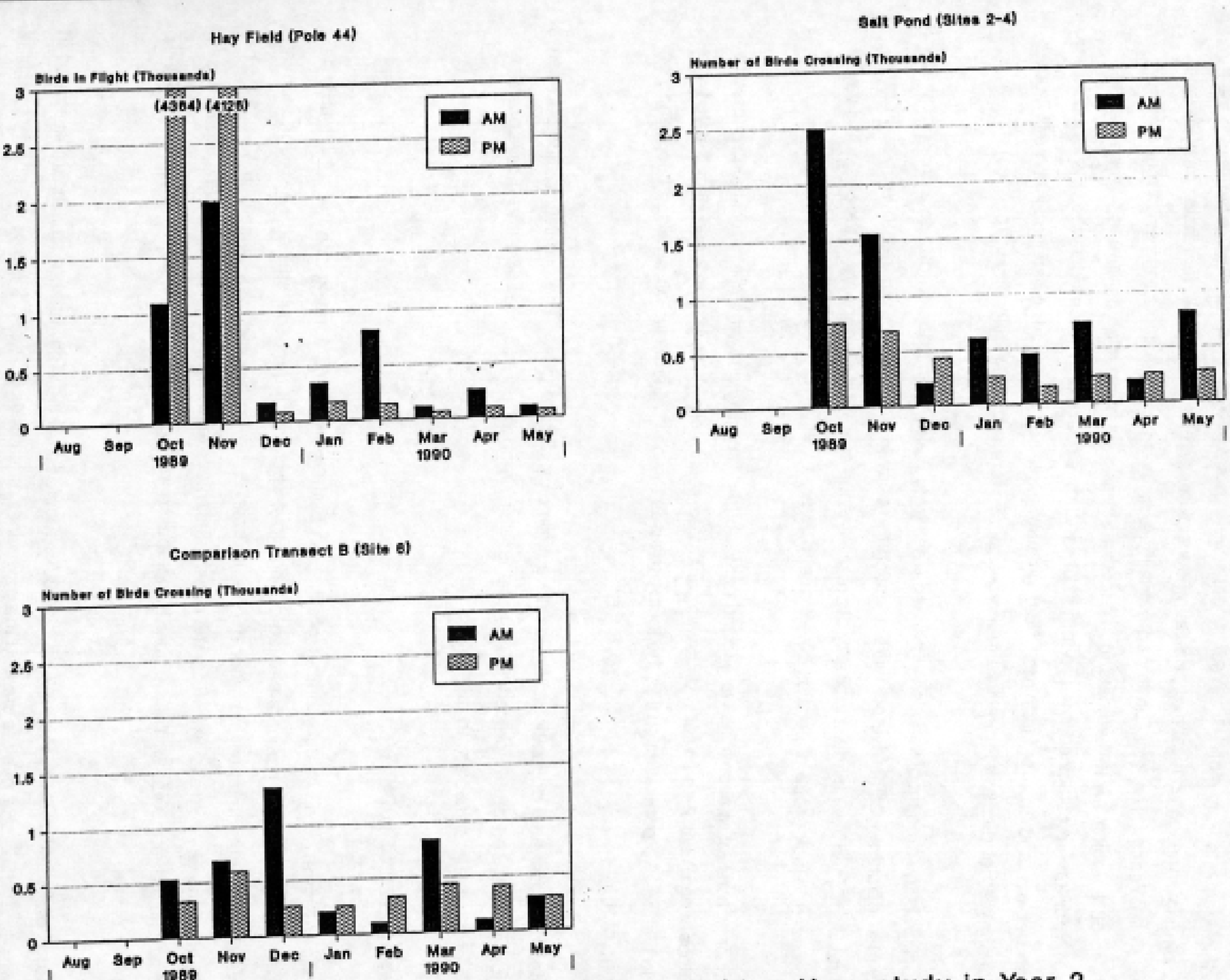


Figure 4-6. Flights per month during daytime flight pattern study in Year 2.

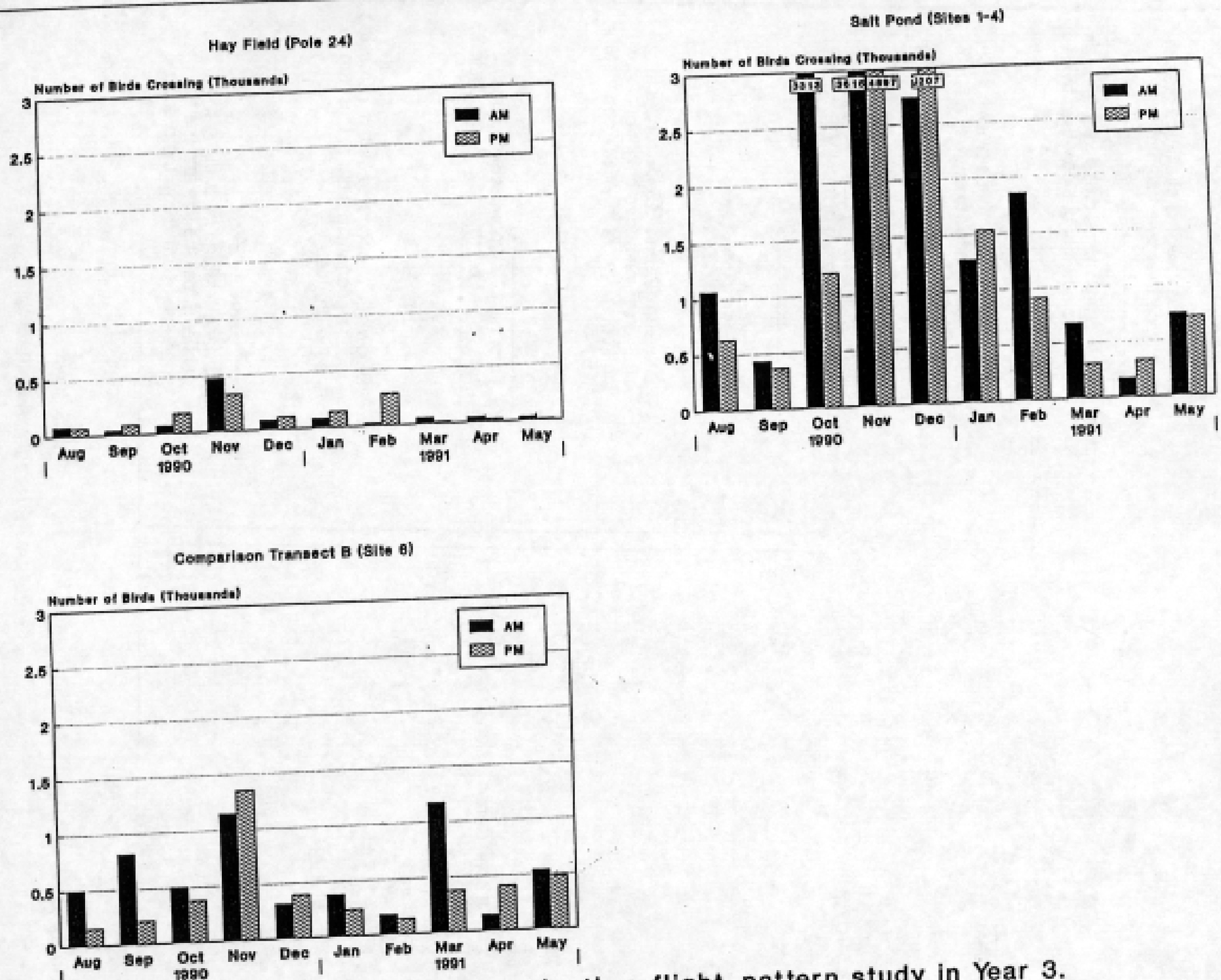


Figure 4-7. Flights per month during daytime flight pattern study in Year 3.

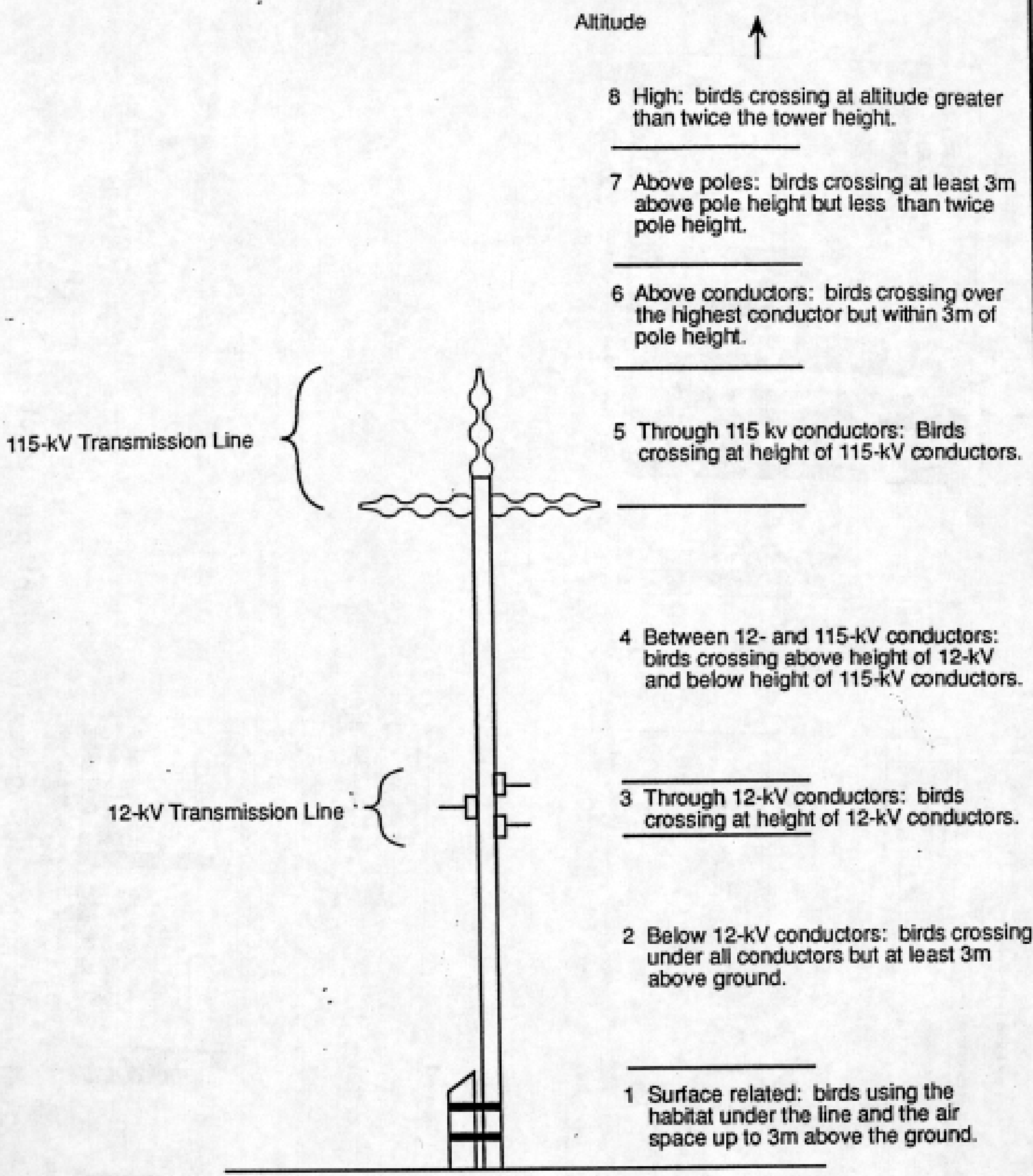
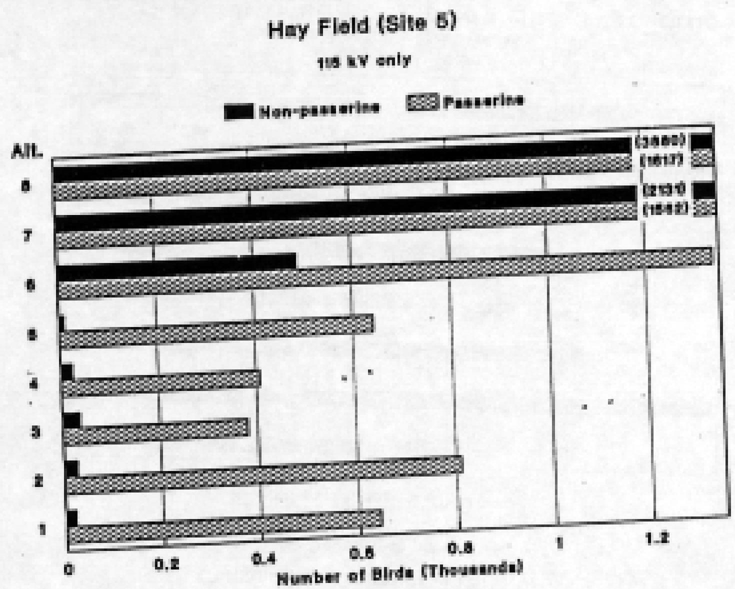
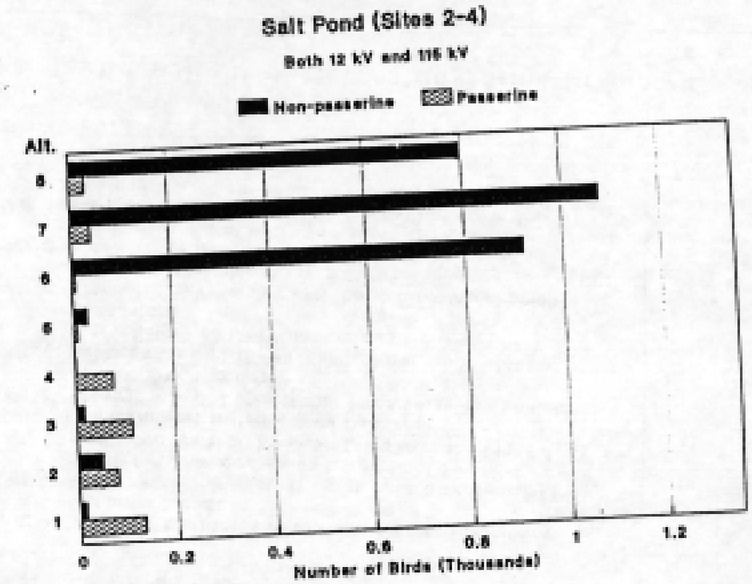
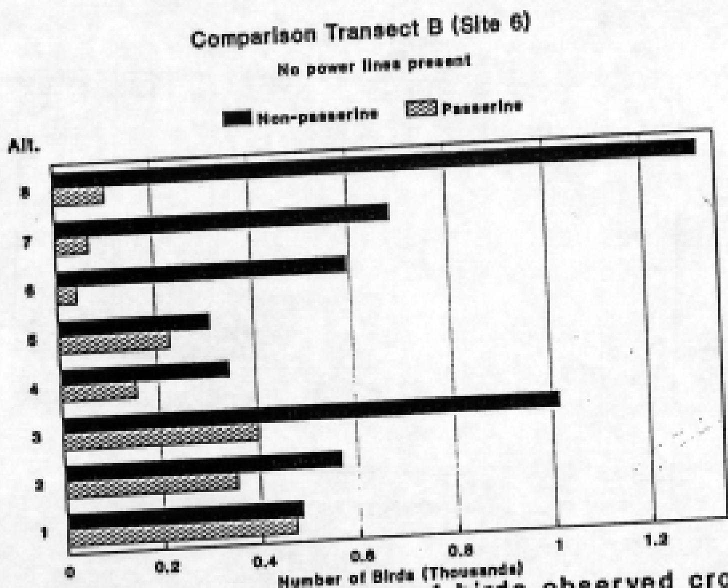


Figure 4-8. Flight pattern altitudes.



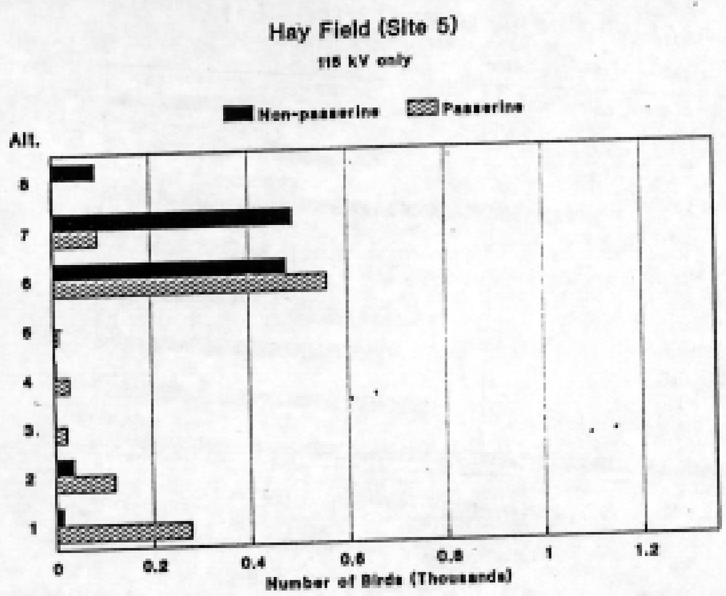


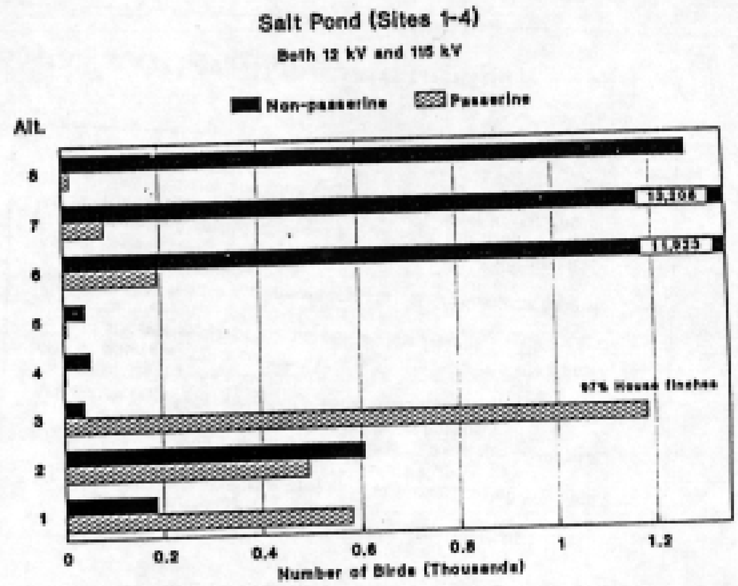


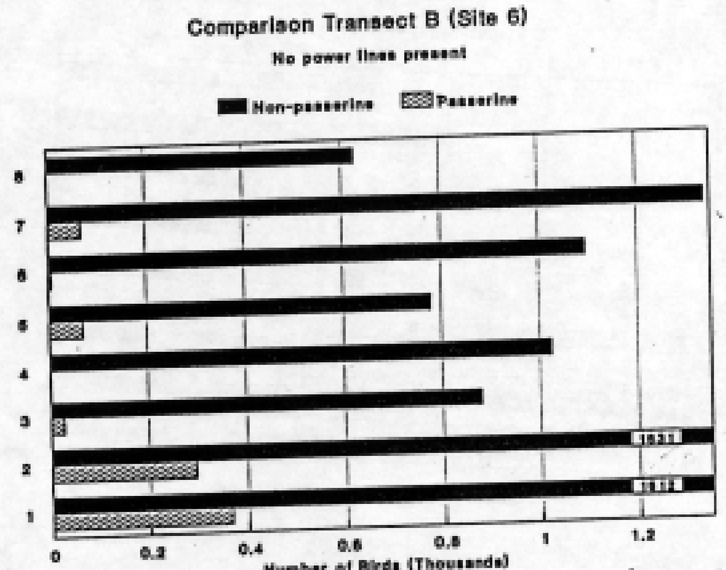
Flight Pattern Altitudes

Alt. 8 High: birds crossing at altitude greater than twice the tower height.
Alt. 7 Above poles: birds crossing at least 3 m above pole height but less than twice pole height.
Alt. 6 Above conductors: birds crossing over the highest conductor but within 3 m of pole height.
Alt. 5 Through 115-kV conductors: birds crossing at height of 115-kV conductors.
Alt. 4 Between 12- and 115-kV conductors: birds crossing above height of 12-kV and below height of 115-kV conductors.
Alt. 3 Through 12-kV conductors: birds crossing at height of 12-kV conductors.
Alt. 2 Below 12-kV conductors: birds crossing under all conductors but at least 3 m above the ground.
Alt. 1 Surface related: birds using the habitat under the line and the air space up to 3 m above the ground.

Figure 4-9. Altitudes of birds observed crossing the daytime flight pattern study sites in Year 2.







Flight Pattern Altitudes

Alt. 8 High: birds crossing at altitude greater than twice the tower height.

Alt. 7 Above poles: birds crossing at least 3 m above pole height but less than twice pole height.

Alt. 6 Above conductors: birds crossing over the highest conductor but within 3 m of pole height.

Alt. 5 Through 115-kV conductors: birds crossing at height of 115-kV conductors.

Alt. 4 Between 12- and 115-kV conductors: birds crossing above height of 12-kV and below height of 115-kV conductors.

Alt. 3 Through 12-kV conductors: birds crossing at height of 12-kV conductors.

Alt. 2 Below 12-kV conductors: birds crossing under all conductors but at least 3 m above the ground.

Alt. 1 Surface related: birds using the habitat under the line and the air space up to 3 m above the ground.

Figure 4-10. Altitudes of birds observed crossing the daytime flight pattern study sites in Year 3.

Very few non-passerines were seen crossing at altitudes 1 - 5. A notable exception is the group of birds (primarily shorebirds) crossing the salt pond at altitude 2 during Year 3. At CTB, by comparison, the non-passerine flight altitudes are much more evenly distributed.

Reactions of Birds Crossing Powerlines. CTB provided a comparison for how birds react when a powerline is not present. Fewer than 10% of either non-passerines or passerines displayed any reaction when they crossed the CTB transect (Table 4-8). By contrast, the majority of birds reacted to the powerlines when crossing the hay field or the salt pond transect. The exception was that in Year 2, the flight pattern sampling location in the hayfield included a large eucalyptus tree. Passerines which used this eucalyptus tree adjacent to the powerline as a roost site generally did not react to the presence of the powerline. In Year 3 the location of the flight pattern transect in the hayfield was moved to more accurately reflect the hayfield environment (virtually no trees are present in the hayfield transect). In Year 3, passerines reacted 83% of the time when crossing the powerline in the hayfield transect.

Four groups of birds (ducks, plovers, peeps, and shorebirds) were examined in detail to see how they reacted between the three transects (Table 4-8). Over 90% of ducks, plovers and all non-passerines, and 75% of passerines reacted to the salt pond transect powerline. Over 95% of plovers and 74% of all non-passerines reacted to the hayfield transect powerline but less than 43% of passerines and ducks reacted. As described above, passerine reactions were probably biased to show fewer reactions than actually occurred because of the location of the Year 2 hayfield transect. Each of the four groups reacted less than 10% of the time when crossing the CTB transect.

Flight Direction. The most common flight directions of non-passerines flying over the salt pond transect in the morning were west, east and northeast at all four sites during Year 3. In Year 2, west and east were the most common (Figures 4-11 and 4-12). The PM non-passerine flight directions over the salt pond for both years also vary between sites. The small amount of passerine data in the salt pond provides no obvious direction trend.

In the hay field, non-passerines flew predominantly southwest in the evening in both years. The smaller number of morning flights were more evenly distributed. Passerine flight directions in the hay field vary greatly between Years 2 and 3. In year 2, morning flights were very evenly divided; however, in Year 3 more birds are flying northeast and southwest. The limited evening passerine data in Year 3 shows a slight peak in southwest flights, but Year 2 shows evening flights to be predominantly northwest and southeast.

Non-passerines flew primarily east-west in CTB in both years. The directions of the fewer of passerine flights recorded were more evenly distributed.

Table 4-8 . Reaction of birds crossing the transects during daytime surveys at altitudes of risk during Years 2 and 3 by transect and bird group.

Non-passerines[1]

Reaction	Hay Field[2]	Salt Pond[3]	CTB[3]
No reaction	26%	7%	95%
Swerve & over	8%	13%	2%
Swerve & under	1%	2%	+%
Over & swerve	4%	7%	2%
Turn & leave	1%	1%	0%
Collide & fly	0%	0%	0%
Collide & fall	0%	+%	0%
Land on line	+%[4]	+%	0%
Swerve up then down[5]	59%	68%	1%
Total	668	15,755	8,203

Passerines

Reaction	Hay Field	Salt Pond	CTB
No reaction	57%	25%	93%
Swerve & over	6%	2%	0%
Swerve & under	7%	5%	0%
Over & swerve	8%	1%	7%
Turn & leave	7%	10%	0%
Collide & fly	0%	+%	0%
Collide & fall	0%	+%	0%
Land on line	+%	52%	0%
Swerve up then down	15%	5%	+%
Total	3,085	2,534	1,570

Ducks

Reaction	Hay Field	Salt Pond	CTB
No reaction	61%	3%	91%
Swerve & over	0%	5%	4%
Swerve & under	9%	0%	+%
Over & swerve	3%	2%	3%
Turn & leave	0%	0%	0%
Collide & fly	0%	0%	0%
Collide & fall	0%	0%	0%
Land on line	0%	0%	0%
Swerve up then down	27%	90%	1%
Total	33	175	2908

Plovers

Reaction	Hay Field	Salt Pond	CTB
No reaction	4%	2%	100%
Swerve & over	7%	3%	0%
Swerve & under	0%	2%	0%
Over & swerve	0%	3%	0%
Turn & leave	0%	1%	0%
Collide & fly	0%	0%	0%
Collide & fall	0%	0%	0%
Land on line	0%	0%	0%
Swerve up then down	89%	89%	0%
Total	140	3,390	218

Table 4-8. (cont.)

Peeps[6]

Reaction	Hay Field	Salt Pond	CTB
No reaction	22%	4%	95%
Swerve & over	12%	13%	0%
Swerve & under	0%	4%	+%
Over & swerve	7%	7%	2%
Turn & leave	0%	+%	0%
Collide & fly	0%	0%	0%
Collide & fall	0%	+%	0%
Land on line	0%	0%	0%
Swerve up then down	59%	72%	2%
Total	358	6,270	1,078

Shorebirds[7]

Reaction	Hay Field	Salt Pond	CTB
No reaction	17%	3%	97%
Swerve & over	10%	4%	+%
Swerve & under	0%	2%	+%
Over & swerve	5%	2%	+%
Turn & leave	0%	2%	+%
Collide & fly	0%	0%	0%
Collide & fall	0%	+%	0%
Land on line	0%	0%	0%
Swerve up then down	67%	87%	2%
Total	502	9,056	1,224

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[1]All non-passerines combined.
[2]Altitudes 4-6.
[3]Altitudes 2-7.
[4]Number represents less than 1% of the total.
[5]This category not used in Year 2.
[6]Western sandpiper, least sandpiper, and dunlin.
[7]Includes all members of the families Charadriidae, Haematopodidae, Recurvirostridae, and Scolopacidae.

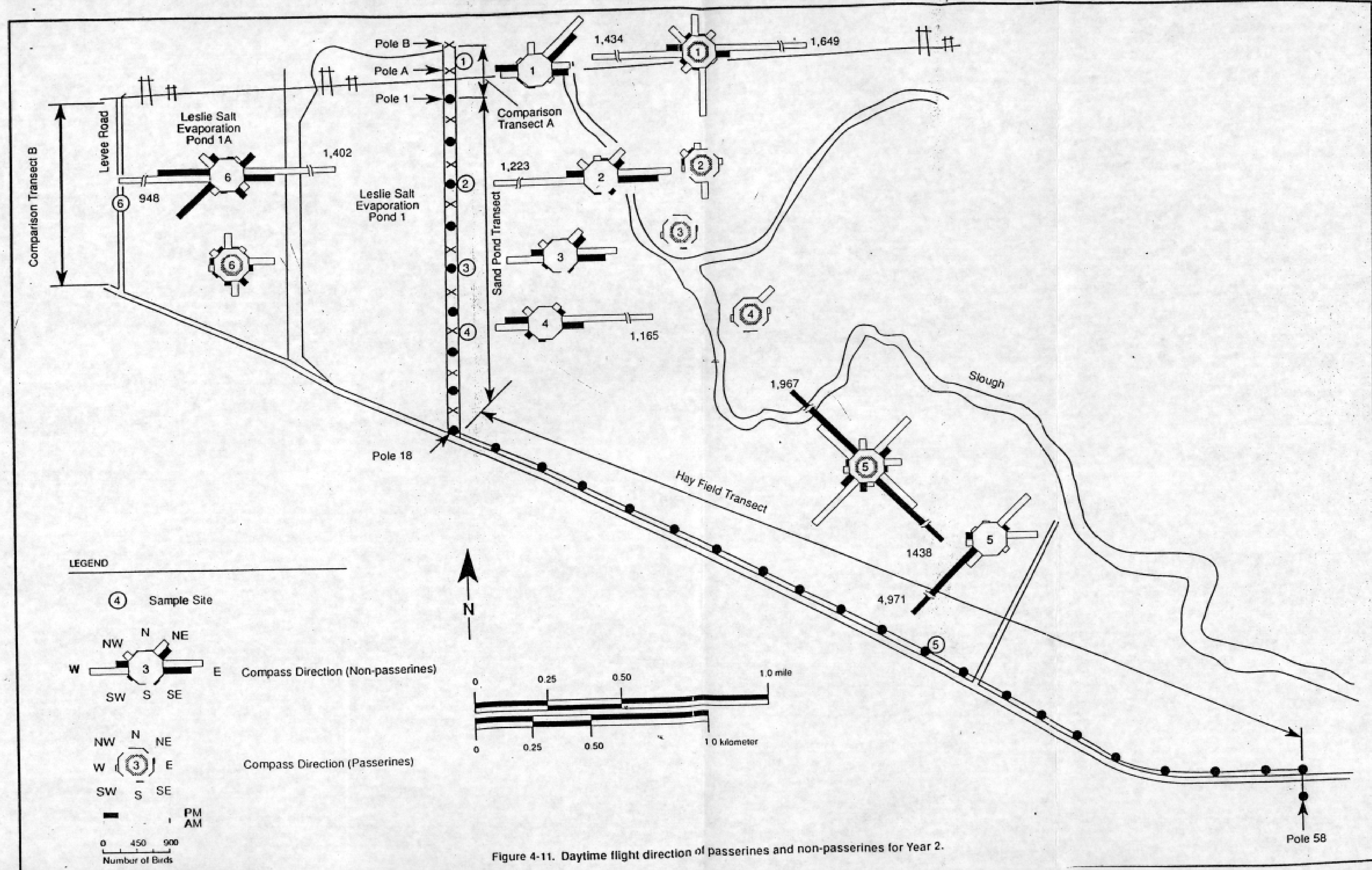


Figure 4-11. Daytime flight direction of passerines and non-passerines for Year 2.

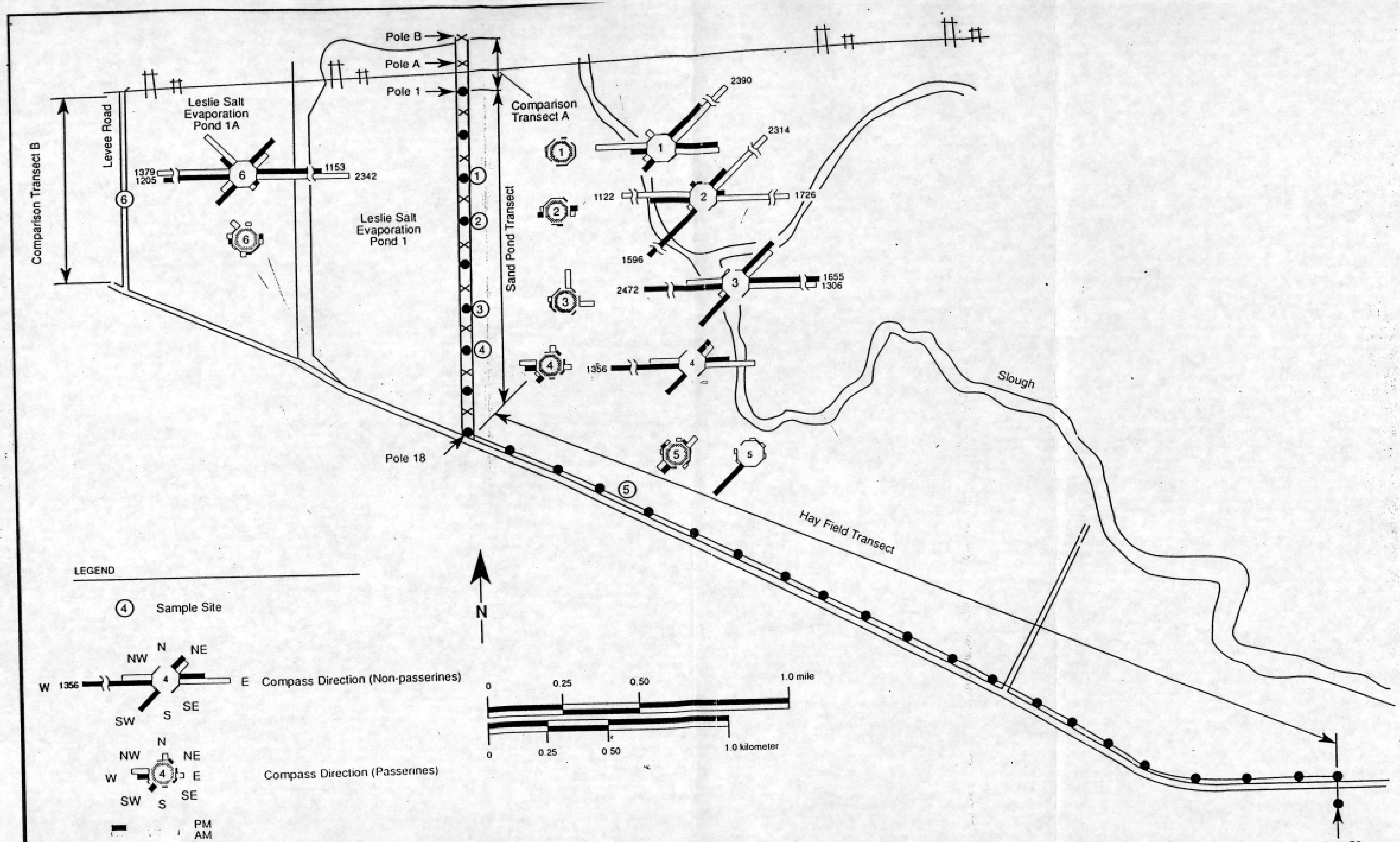


Figure 4-12. Daytime flight direction of passerines and non-passerines for Year 3.

Night Study

Time and Number of Birds Crossing. The night flight pattern observers recorded the majority of bird crossings in Year 3 at times near sunrise or sunset (Figure 4-13). However, many crossings occurred in the middle of the night in August, September, October, April, and May. Observations were not made throughout the night in Year 2, so it is not possible to determine whether flights were concentrated near sunset and sunrise. In addition, the observation equipment and methods were being refined during Year 2, making direct comparisons with Year 3 difficult.

Altitudes of Birds Crossing Powerlines. As in the daytime surveys, the majority of non-passerines were observed crossing the powerlines at altitudes 6, 7, or 8 (Figure 4-14). Flight altitude 6, considered at-risk, represents 20% of the non-passerine flights in the salt pond over the two years. The passerine altitudes were more evenly distributed in the salt pond, especially in Year 2. No passerines were seen crossing the salt pond transect at altitudes 7 or 8.

Reactions of Birds Crossing Powerlines. The majority of all birds observed crossing the powerlines at night did not react (Table 4-9). Over two years, five birds were observed colliding with the line and flying away. Four birds, all in Year 3, were observed colliding and falling from the line. Birds that collided and continued flying were one shorebird and four unidentified non-passerines. Birds that collided and fell were one duck, one shorebird, and two unidentified non-passerines.

Flight Direction. The majority of non-passerines seen flying across powerlines at night in both years flew east or west (Figure 4-15). Too few passerines were observed to reveal a trend.

	Aug.	Sept.	Oct.	Nov.	Dec.
Sunrise	0605	0631	0657	0632	0658
Sunset	2006	1927	1841	1655	1641

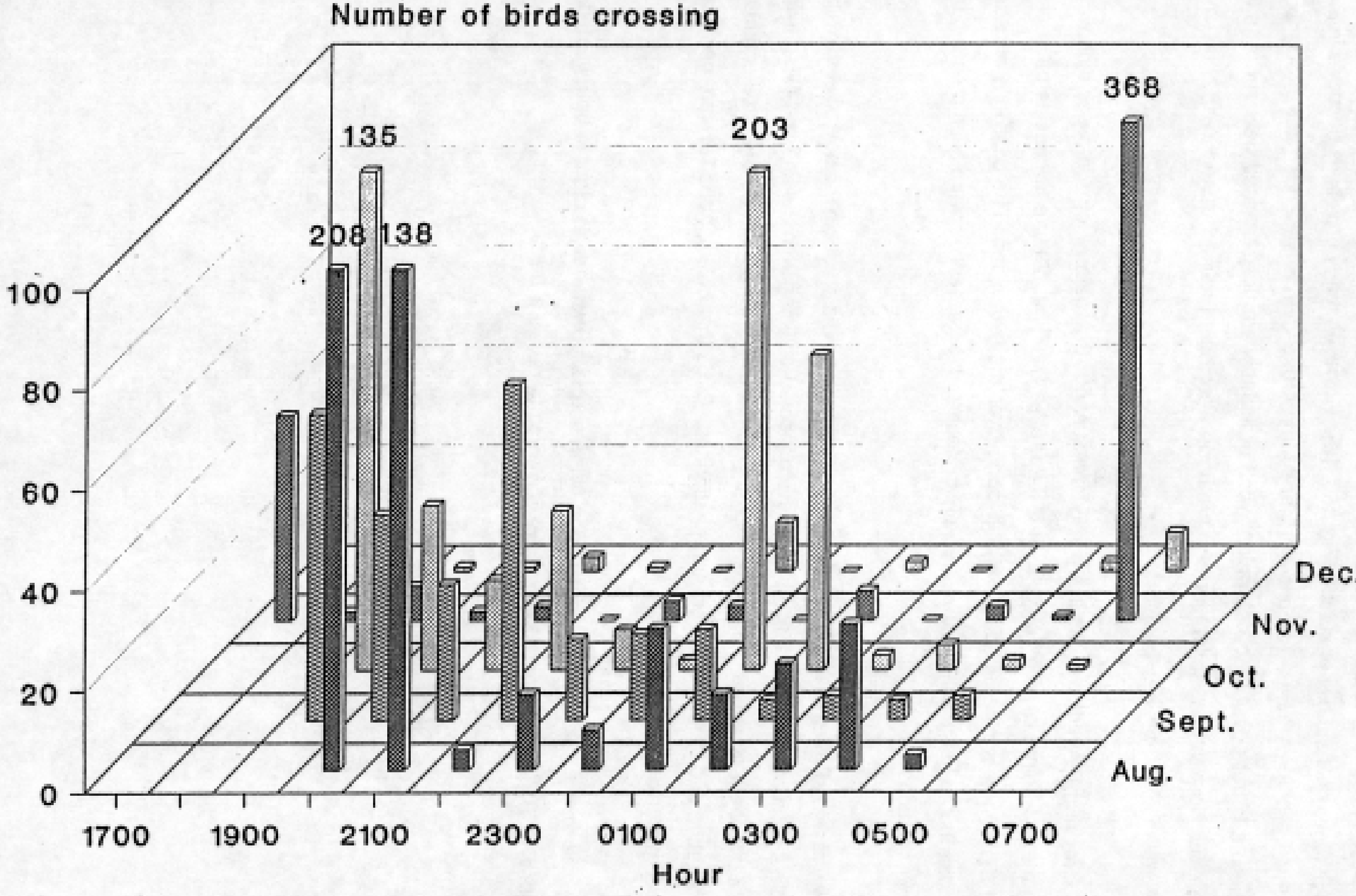


Figure 4-13a. Night flight pattern data: Number of birds crossing in August-December of Year 3 by date and time. Note sunset and sunrise times.

	Jan.	Feb.	Mar.	Apr.	May
Sunrise	0716	0706	0624	0541	0605
Sunset	1655	1721	1759	1825	1950

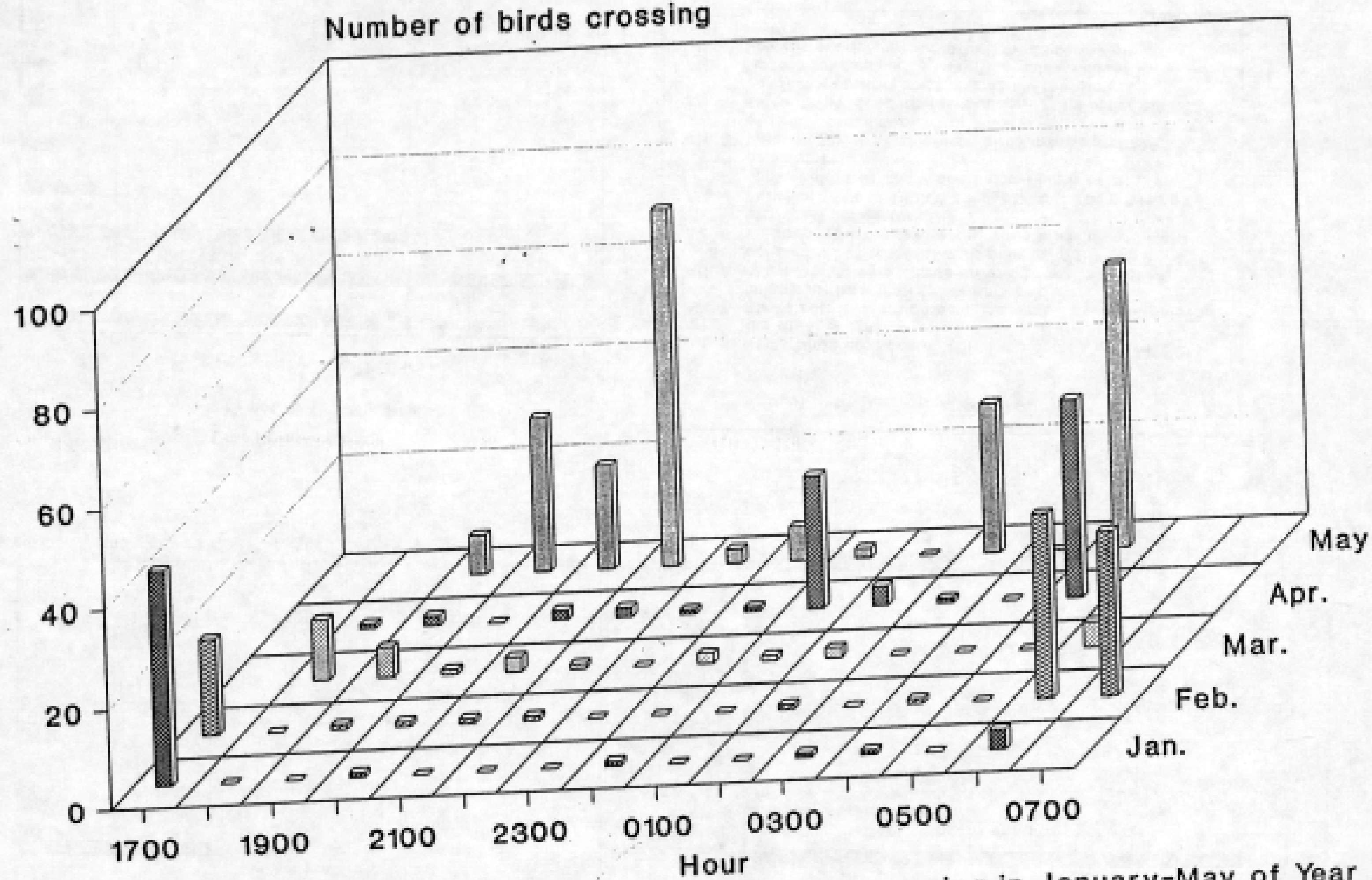
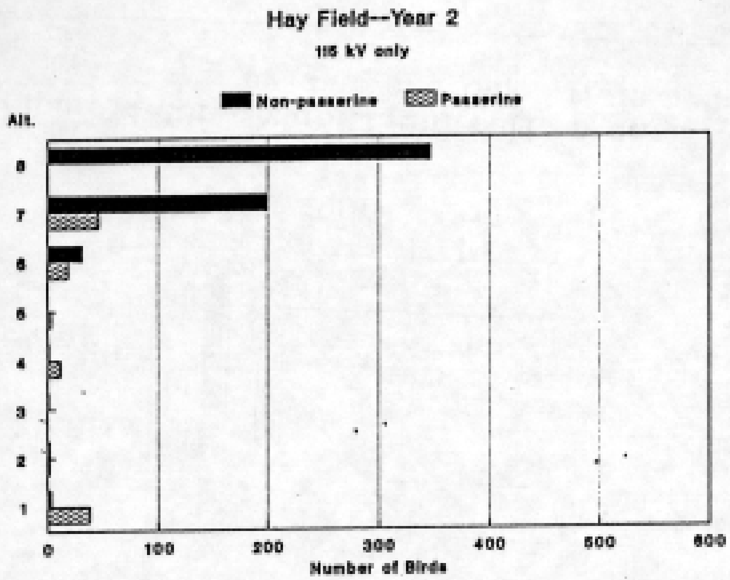
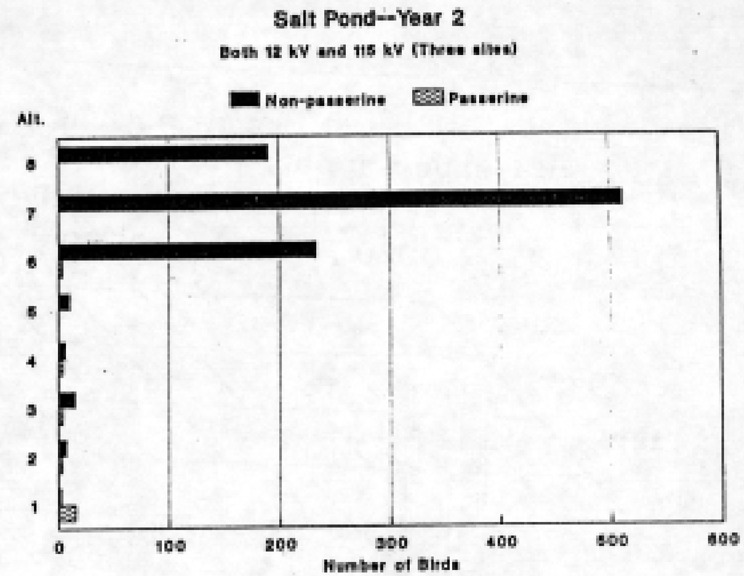
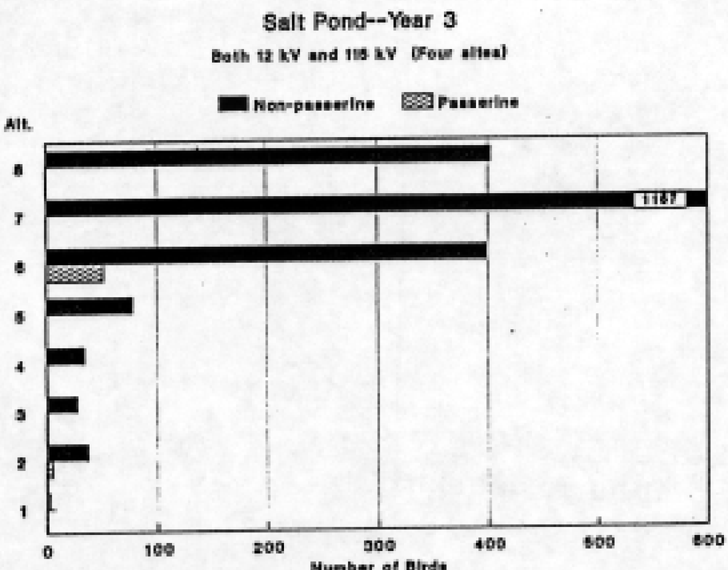


Figure 4-13b. Night flight pattern data: Number of birds crossing in January-May of Year 3 by date and time. Note sunset and sunrise times.







Flight Pattern Altitudes

Alt. 8 High: birds crossing at altitude greater than twice the tower height.
Alt. 7 Above poles: birds crossing at least 3 m above pole height but less than twice pole height.
Alt. 6 Above conductors: birds crossing over the highest conductor but within 3 m of pole height.
Alt. 5 Through 115-kV conductors: birds crossing at height of 115-kV conductors.
Alt. 4 Between 12- and 115-kV conductors: birds crossing above height of 12-kV and below height of 115-kV conductors.
Alt. 3 Through 12-kV conductors: birds crossing at height of 12-kV conductors.
Alt. 2 Below 12-kV conductors: birds crossing under all conductors but at least 3 m above the ground.
Alt. 1 Surface related: birds using the habitat under the line and the air space up to 3 m above the ground.

Figure 4-14. Altitudes of birds observed crossing the night flight pattern study sites in Years 2 and 3.

Table 4-9. Reaction of birds crossing the transects during night surveys at altitudes of risk during Years 2 and 3 by transect and bird group. Note that the hay field was only done in Year 2.

Non-passerines	Reaction	Hay Field[1]	Salt Pond[2]
	No reaction	100%	72%
	Swerve & over	0%	12%
	Swerve & under	0%	1%
	Over & swerve	0%	4%
	Turn & leave	0%	2%
	Collide & fly	0%	1%
	Collide & fall	0%	+%[3]
	Land on line	0%	1%
	Swerve up then down[4]	N/A	7%
	Total	32	841

Passerines	Reaction	Hay Field	Salt Pond
	No reaction	89%	98%
	Swerve & over	11%	0%
	Swerve & under	0%	0%
	Over & swerve	0%	0%
	Turn & leave	0%	2%
	Collide & fly	0%	0%
	Collide & fall	0%	0%
	Land on line	0%	0%
	Swerve up then down	N/A	0%
	Total	18	62

Ducks	Reaction	Hay Field	Salt Pond
	No reaction	100%	46%
	Swerve & over	0%	17%
	Swerve & under	0%	2%
	Over & swerve	0%	26%
	Turn & leave	0%	2%
	Collide & fly	0%	0%
	Collide & fall	0%	2%
	Land on line	0%	0%
	Swerve up then down	N/A	4%
	Total	3	46

Plovers	Reaction	Hay Field	Salt Pond
	No reaction	100%	83%
	Swerve & over	0%	0%
	Swerve & under	0%	17%
	Over & swerve	0%	0%
	Turn & leave	0%	0%
	Collide & fly	0%	0%
	Collide & fall	0%	0%
	Land on line	0%	0%
	Swerve up then down	N/A	0%
	Total	11	12

Table 4-9. (cont.)

Peeps[5]

Reaction	Hay Field	Salt Pond
No reaction	100%	66%
Swerve & over	0%	24%
Swerve & under	0%	1%
Over & swerve	0%	4%
Turn & leave	0%	2%
Collide & fly	0%	0%
Collide & fall	0%	0%
Land on line	0%	0%
Swerve up then down	N/A	3%
Total	3	278

Shorebirds

Reaction	Hay Field	Salt Pond
No reaction	100%	74%
Swerve & over	0%	14%
Swerve & under	0%	1%
Over & swerve	0%	5%
Turn & leave	0%	1%
Collide & fly	0%	+%
Collide & fall	0%	+%
Land on line	0%	0%
Swerve up then down	N/A	4%
Total	17	502

[1]Altitudes 4-6. Year 2 only.
[2]Altitudes 2-7.
[3]Number represents less than 1% of the total.
[4]This category not used in Year 2.
[5]Western sandpiper, least sandpiper, and dunlin.

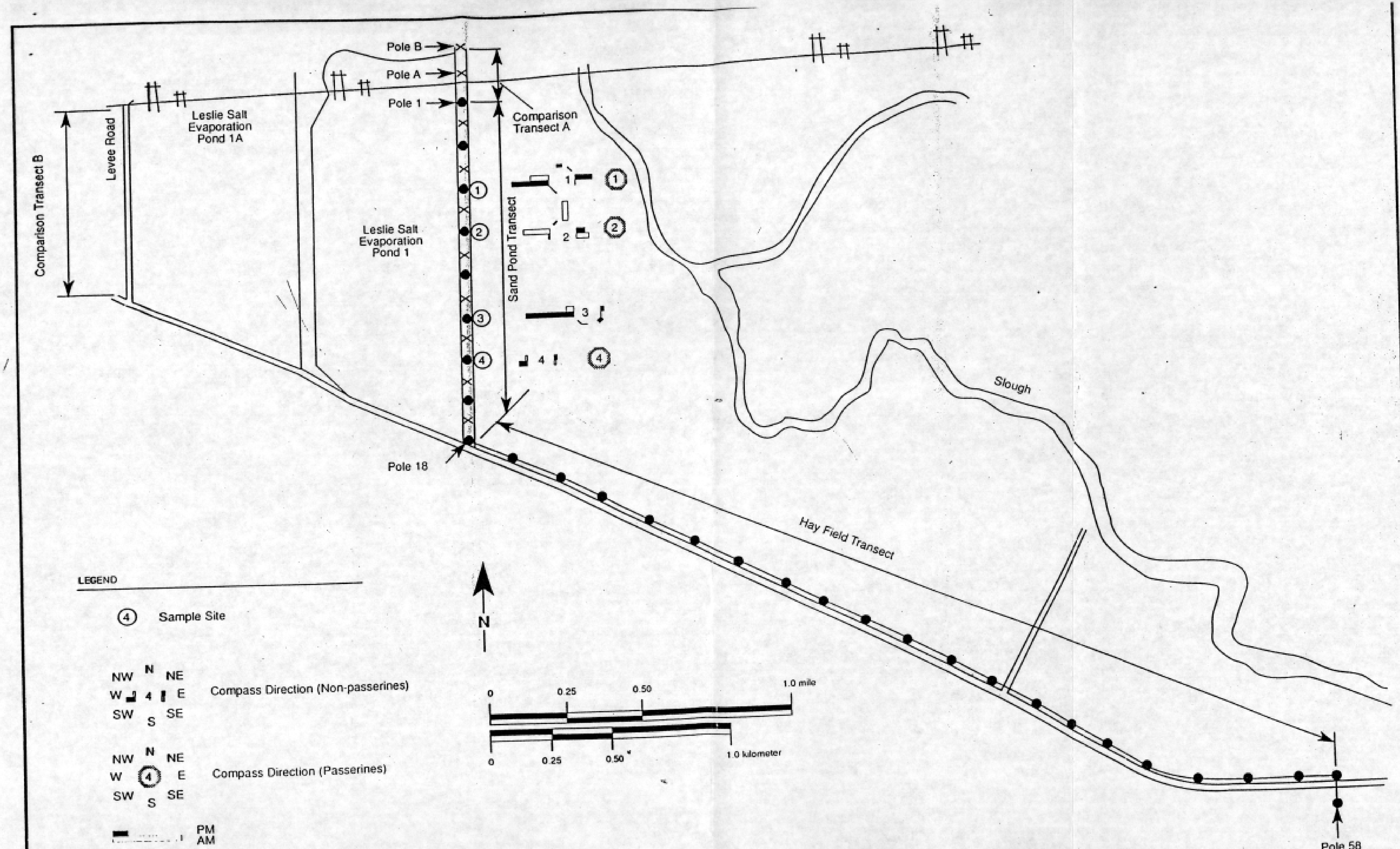


Figure 4-15. Nighttime flight direction of passerines and non-passerines for Year 3 (all months). Scale is twice as large as daytime.

Section 5

DISCUSSION

MORTALITY

Estimated Mortality

Although a statistically valid test could not be performed to state whether the hay field and salt pond estimates were significantly different, the consistency and magnitude in difference between the three years of study support the likelihood that the difference is not due to chance. More importantly, the obvious relationship of the proximity of birds using the salt pond and the greater number of mortalities observed in the adjacent transect provides a clear explanation for the difference in recoveries from the two transects.

Faanes (1987) had described his study areas as worst-case sites, according to his opinion. The estimated bird mortality per hectare per week in the salt pond transect is from 2.6 to 5.1 times that found in Faanes' (1987) locations (Table 4-7). Also, estimated salt pond mortality has been nearly nine times greater in the salt pond transect compared with the hay field transect. Thus, compared to other studies, and compared with the hay field transect, collisions with the powerlines in the salt pond transect are noticeably more serious.

Cause of Death

Trauma and suspect trauma were the primary known causes of death. The typical injuries of wing severing, and head, thoracic, and abdominal trauma were consistent with collision with a powerline or guy wire.

FLIGHT PATTERN STUDY

Flight Altitudes and Reactions

There is a distinct difference in the altitudes of different species while crossing transects with and without powerlines, indicating that most birds are aware of the line. Although birds generally tend to fly over the lines, many non-passerines tend to fly just above the lines and many passerines fly at or below the lines. However, in Year 3, over 500 shorebirds flew just below the 12-kV conductor. This information is of particular interest in the salt pond transect, where transmission and distribution conductors share the same poles. Because the few collisions witnessed were at night, we were unable to determine exactly which conductors were involved.

During the daytime, the majority of birds reacted to the powerlines, but at night, a much smaller percentage did. It is more difficult for observers to see the reactions of birds at night, especially if birds are small or moving swiftly. Consequently, some reactions, especially those that are subtle, may go unnoticed. Still, many birds probably do not see the line in the dark, are not reacting, and are therefore prone to collisions.

Bird Mortality as Related to Powerline Crossings

For each transect, we selected species with high mortality or high numbers of at-risk crossings during Years 2 and 3 (Table 5-1). The table reveals species which may be susceptible to powerline collisions.

In the hay field, savannah sparrows stand out because they have been found in high numbers compared to the number of crossings observed by flight pattern observers. Necropsy results over the past two years listed trauma or suspect trauma as cause of death for 11 out of 14 intact savannah sparrows recovered in the hay field and salt pond. Sparrows are night migrants, which would explain why so few were recorded crossing the line in the hay field. In addition, almost all savannah sparrows were found in the hay field in the fall. In the salt pond, their mortality was more evenly distributed throughout the year, and they were also recorded much more frequently by flight pattern observers. Savannah sparrows found in the hay field, therefore, were probably migrating birds flying through at night, whereas the sparrows in the salt pond were most likely part of a local population.

Like the savannah sparrows in the hay field, ruddy ducks had high mortalities in the salt pond and yet were rarely seen crossing the powerline. Unfortunately, none of the ruddy ducks recovered in the last two years were candidates for necropsy. Other researchers have found ruddy ducks to be vulnerable to wire strikes. One suggestion for such vulnerability is the fact that they normally fly only during and after dusk. This behavior would explain why our observers saw so few ruddy ducks during the day. In addition, they do not climb steeply after taking wing. Instead, they often fly in a low, wide circle to gain altitude (Siegfried 1972). Again, this behavior could increase the likelihood of wire strikes. Most ruddy ducks observed during our flight pattern surveys flew low and showed no reaction to the line, indicating that they simply did not see it.

In contrast to ruddy ducks, many western sandpipers crossed the powerlines during the day. Sandpipers fly across the powerlines in fast, tight flocks. The high percentage of at-risk crossings suggests that they may be vulnerable to collision. When western sandpipers rapidly cross the wires in mixed flocks, they are often hard to distinguish from least sandpipers and dunlins, and are therefore often recorded as "peeps." The percentage of at-risk crossings and mortality indices are both lower for peeps. Still, some researchers consider that shorebirds are more exposed to collisions with wires than other species because of their flight behavior (Andersen-Harild and Bloch 1973). For example, in our study 16,857 gulls and terns crossed the powerline in the salt pond, and yet only 24 were recovered in mortality searches.

More dunlins were recovered than western sandpipers, and a very high number of dunlins were seen crossing the lines. Like the western sandpiper, we have often seen dunlin crossing the lines at low altitudes in tightly bunched, fast-moving flocks. We have often observed the lead birds in flocks making abrupt

Table 5-1. Species with either a high number of mortalities or a high number of daytime powerline crossings during Years 2 and 3. Bullet indicates species found in both categories.

HAY FIELD (no 12-kV)

Species	Mortalities	At-Risk Crossings[1]	All Crossings	RC/AC[2]	M/RC Index[3]	M/AC Index[4]
High Number of Mortalities (≥ 6 mortalities)						
• Western sandpiper	6	30	349	8.6%	20.0	1.7
Rock dove	7	35	96	36.5%	20.0	7.3
Savannah sparrow	13	0	20	.0%	n.d.[5]	65.0
• Red-winged blackbird	6	956	4527	21.1%	0.6	0.1
• Western meadowlark	8	310	876	35.4%	2.6	0.9
High Number of Crossings (≥ 250 crossings)						
Black-bellied plover	3	151	1056	14.3%	2.0	0.3
• Western sandpiper	6	30	349	8.6%	20.0	1.7
Dunlin	1	616	4583	13.4%	0.2	.0
All peeps	7	701	5345	13.1%	1.0	0.1
California gull	0	0	273	.0%	n.d.	.0
European starling	3	255	258	98.8%	1.2	1.2
• Red-winged blackbird	6	956	4527	21.1%	0.6	0.1
• Western meadowlark	8	310	876	35.4%	2.6	1.0
Brewer's blackbird	3	818	1590	51.4%	0.4	0.2
House finch	2	575	843	68.2%	0.3	0.2

SALT POND

Species	Mortalities	At-Risk Crossings[6]	All Crossings	RC/AC[2]	M/RC Index[3]	M/AC Index[4]
High Number of Mortalities (≥ 20 mortalities)						
Ruddy duck	30	0	24	.0%	n.d.	125.0
American coot	20	0	0	n.d.	n.d.	n.d.
• Black-bellied plover	69	3381	3991	84.7%	2.0	1.7
• Western sandpiper	39	627	787	79.7%	6.2	5.0
• Dunlin	60	3392	4638	73.1%	1.8	1.3
• Savannah sparrow	22	43	532	8.1%	51.2	4.1
High Number of Crossings (≥ 500 crossings)						
Double-crested cormorant	1	394	637	61.9%	0.3	0.2
Northern pintail	1	81	1019	7.9%	1.2	0.1
• Black-bellied plover	69	3381	3991	84.7%	2.0	1.7
• Western sandpiper	39	627	787	79.7%	6.2	5.0
• Dunlin	60	3392	4638	73.1%	1.8	1.3
All peeps	107	6431	10,093	63.7%	1.7	1.1
Dowitcher species	15	567	967	58.6%	2.6	1.6
Bonaparte's gull	2	562	911	61.7%	3.9	0.2
California gull	14	394	2035	19.4%	3.6	0.7
Western gull	0	187	507	36.9%	.0	.0
Glaucous-winged gull	0	85	683	12.4%	.0	.0
Forster's tern	0	800	1055	75.8%	.0	.0
• Savannah sparrow	22	43	532	8.1%	51.2	4.1
Western meadowlark	12	334	520	64.2%	3.6	2.3
House finch	9	1103	2111	52.3%	0.8	0.4

Table 5-1. (continued)

COMPARISON TRANSECT B (no power lines)

Species	Mortalities	At-Risk Crossings[6]	All Crossings	RC/AC[2]	M/RC Index[3]	M/AC Index[4]
High Number of Mortalities ($\geq$ 3 mortalities)						
Canvasback	5	89	122	73.0%	5.6	4.1
Ruddy duck	13	36	44	81.8%	36.1	29.5
Black-bellied plover	7	210	242	86.8%	3.3	2.9
• Least sandpiper	3	193	304	63.5%	1.6	0.1
• Dunlin	15	531	823	64.5%	2.8	1.8
• House finch	5	1045	1499	69.7%	0.5	0.3
High Number of Crossings ($\geq$ 300 crossings)						
Double-crested cormorant	2	249	556	44.8%	0.8	0.4
Mallard	0	213	302	70.5%	.0	.0
Northern pintail	1	298	977	30.5%	0.3	0.1
Northern shoveler	2	1893	2281	83.0%	0.1	0.1
• Least sandpiper	3	193	304	63.5%	1.6	1.0
• Dunlin	15	531	823	64.5%	2.8	1.8
Peep species	20	1152	2082	55.3%	1.7	1.0
Ring-billed gull	1	202	300	67.3%	0.5	0.3
California gull	0	225	452	49.8%	.0	.0
Gull species	1	2091	4764	43.9%	.0	.0
Forster's tern	0	573	625	91.7%	.0	.0
• House finch	5	1045	1499	69.7%	0.5	0.3

[1]At risk crossing=altitudes 4-6 (near powerlines).
[2]Ratio percent of risk crossings to all crossings recorded.
[3]Ratio of mortalities to risk crossings * 100.
[4]Ratio of mortalities to all crossings * 100.
[5]n.d. = No data.
[6]At risk crossing=altitudes 2-6 (near powerlines).

changes in course and altitude (usually a fast climb over the top conductor), while the trailing birds in the flock appear to lose their orientation to the powerlines. Other researchers who have observed collisions noted that the trailing bird of the flock was involved. The lead birds may have blocked the view of those in the rear, leaving them with no time or space to react (James and Haak 1979).

Black-bellied plovers were reported in high numbers both as mortalities and by flight pattern observers. Black-bellied plovers are powerful, swift fliers that feed in both the hay field and the salt pond. Almost all plovers crossed the lines at Altitude 6, just above the transmission line. Their swift flight close to the lines and habit of crossing between the salt pond and hay field to feed may make them susceptible to collisions.

THE SIGNIFICANCE OF TRANSMISSION LINE MORTALITY

It is difficult to accurately determine whether powerline collision mortality is having a significant effect on the bird species involved in this study. Detailed data on population size, the rate of population turnover during migration, reproductive success, and the extent to which powerline mortality replaces other mortality of each bird species present is not available. Definitive information on all such factors would be extremely expensive and possibly impractical to obtain. In the absence of this information, an analysis based on the best information available is all that is possible. The following discussion is based on the actual observations of carcasses and feather spots found on the study area, estimates of average monthly losses from the powerline found on the study area, bird-powerline studies in other locations, the local bird populations observed in the adjacent salt ponds, and regional San Francisco Bay area bird population census estimates. The Mare Island transmission line is one of many mortality factors affecting the birds in the San Francsico Bay Area. A cumulative effects analysis of all migratory bird mortality factors in the vicinity of this project is beyond the scope of this study.

In this study the Navy agreed to use an estimated crippling bias factor of 74%. The use of a crippling bias factor of 74% is probably inappropriate. The 74% crippling bias factor is an average of several figures calculated by Beaulaurier (1981) who advised against its use in other studies. Except where specifically stated, the numbers reported in the following discussion are not adjusted to include a 74% crippling bias.

We analyzed mortality by groups of species and selected five species with high mortality to compare with their local salt pond population and their populations in the greater San Francsisco Bay. The average monthly mortality for the three-year study and regional population censuses of ruddy ducks, black-bellied plovers, least and western sandpipers, and dunlins is shown in Table 5-2. The significance of collision mortality on these species is included in the following discussion.

Table 5-2. Mortality of selected species in comparison to local populations. Mortality figures are an average of results from Years 1, 2, and 3. Ducks were censused during a U.S. Fish and Wildlife Service Winter Waterfowl Survey. Shorebirds were censused by Point Reyes Bird Observatory Pacific Flyway Project. See footnotes for specific survey dates.

	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
Ruddy ducks										
Actual mortality	1	0	0	2	4	10	9	6	1	1
Est. range: Low[1]	7	1	0	6	13	28	27	18	4	4
High[1]	13	6	1	6	22	71	61	70	18	16
Local pond counts[2]	0	0	157	6	143	1,270	1,747	1,283	1,467	76
U.S.F.W.S. counts						23,288[3]				
Black-bellied plovers										
Actual mortality	9	10	5	3	2	0	1	1	0	0
Est. range: Low	16	21	11	7	13	0	6	2	1	0
High	31	41	23	17	20	0	28	9	1	0
Local pond counts	29	305	329	460	10	0	0	0	0	0
P.R.B.O. counts	12,165[4]	13,205[5]		10,698[6]			11,510[7]		7,462[8]	
Least and western sandpipers										
Actual mortality	2	4	2	2	3	1	1	1	3	5
Est. range: Low	5	9	5	15	22	6	7	1	9	16
High	20	23	6	20	29	6	9	1	38	65
Local pond counts	7,507	14,721	3,964	1,478	2,287	0	0	125	0	0
P.R.B.O. counts	207,209	255,112		132,535			73,744		605,172	
Dunlins										
Actual mortality	0	0	2	10	6	2	0	0	0	1
Est. range: Low	0	1	5	26	40	8	0	0	0	3
High	0	1	11	65	128	9	0	0	0	11
Local Pond counts	0	0	1,267	6,403	4,564	1	0	0	0	0
P.R.B.O. counts	4	19		97,720			42,173		104,362	

[1]Lower and upper values represent lower and upper search biases within a 90% confidence interval plus scavenger and habitat biases plus actual dead birds found.
[2]Average of three daily surveys conducted by flight pattern observers on Leslie Salt Pond 1.
[3]Total count for entire San Francisco Bay region conducted on January 3 and 4, 1991.
[4]Survey conducted August 19, 1989. All P.R.B.O. surveys represent the San Francisco-San Pablo Bay System.
[5]Average of two surveys conducted September 10, 1988 and September 8, 1990.
[6]Survey conducted November 3, 1990.
[7]Average of two surveys conducted January 24-February 24, 1990 and January 27-February 16, 1991.
[8]Average of three surveys conducted April 16, 1988, April 22, 1989, and April 14, 1990.

Hunted Species

During the study, 14 bird species were collected which are subject to legal hunting. These include 12 species of waterfowl (including American coot) and two upland game birds (California quail and mourning dove). Current hunting regulations allow daily bag limits of no more than four ducks per day with not more than two redheads and/or two canvasbacks, not more than one female mallard, not more than two total mallards, and not more than one pintail. Current hunting regulations allow the take of not more than 10 California quail per day and not more than 10 mourning doves per day. An increase in hunting pressure or in the numbers of successful hunters could result in a greater amount of migratory bird mortality than is currently associated with the Mare Island transmission line. This additional hunting mortality could occur without any additional approval being given by any agency.

The lower and upper limits of the range defined in Table 5-2 for the average annual mortality for ruddy ducks in the powerline transects is 108 to 284 birds (sum of monthly figures in Table 5-2). Ruddy duck average annual mortality attributed to the powerline ranges from 0.5% (108/23, 288 x 100) to 1.2% (284/23, 288 x 100) of the maximum San Francisco Bay area population census in Table 5-2. Using a 74% crippling bias factor, annual mortality attributable to the powerline would increase to 0.8% to 2.1% of the maximum San Francisco Bay area population census.

Introduced Species

The rock dove and European starling are species which are non-native to North America and often considered pest species. Any powerline mortality associated with these species is considered to be non-significant.

Loons, Grebes, and Cormorants

It is unlikely that loon, grebe, or cormorant populations were adversely affected by the amount of powerline mortality observed in this study. Only 1-2 individuals per species per year were collected from this group.

Shorebirds

Although 15 species of shorebirds were collected, three common species, black-bellied plover (n = 96), western sandpiper (n = 72), and dunlin (n = 68), accounted for 236 (85%) of 277 shorebirds collected within the powerline transects (Table 4-1 and 4-2).

The estimated range for average annual mortality from Table 5-2 for black-bellied plover in the powerline transects is 77 to 170 birds (sum of monthly figures in Table 5-2). Black-bellied plover average annual mortality ranges from 0.6% (77/13, 205 x 100) to 1.3% (170/13, 205 x 100) of the maximum San Francisco

Bay area population census in Table 5-2. Using a 74% crippling bias factor, annual mortality attributable to the powerline would increase to 1.0% to 2.2% of the maximum San Francisco Bay area population census.

The estimated range for average annual mortality from Table 5-2 for least and western sandpipers in the powerline transects is 79 to 217 birds (sum of monthly figures in Table 5-2). The least and western sandpiper average annual mortality ranges from 0.01% (79/605, 172 x 100) to 0.04% (217/605, 172 x 100) of the maximum San Francisco Bay area population census in Table 5-2. Using a 74% crippling bias factor, annual mortality attributable to the powerline would increase to 0.02% to 0.06% of the maximum San Francisco Bay area population census.

The estimated range for average annual mortality from Table 5-2 for dunlin in the powerline transects is 83 to 225 birds (sum of monthly figures in Table 5-2). The dunlin population also varies greatly by season. Dunlin average annual mortality ranges from 0.08% (83/104, 362 x 100) to 0.2% (225/104, 362 x 100) of the maximum San Francisco Bay area population census in Table 5-2. Using a 74% crippling bias factor, annual mortality attributable to the powerline would increase to 0.1% to 0.4% of the maximum San Francisco Bay area population census.

Rails

Three species of rails, California black rail, Virginia rail, and sora, were collected during the study. The California black rail is a Category 2 candidate for addition to the federal threatened and endangered species list, and is considered a threatened species by the State of California. There were three black rails, two Virginia rails, and four soras, collected during the entire study. Rails are year-round residents in this area (CDFG 1977) so mortality in the project vicinity could directly affect the number of rails available to breed in the local vicinity. This is in contrast to wintering birds where mortality may be dispersed between several different nesting areas.

Rail mortalities occurred in July (two), August (one), September (one), October (three), and November (two). The California clapper rail nesting season is from approximately March 1 to July 15 (Sorenson 1992). Although there is not enough data for a statistical analysis, it may be biologically significant that all mortalities occurred late in the breeding season or after the breeding season. This may indicate that dispersing birds, rather than established local breeding birds, are more vulnerable to powerline mortality. A conclusive determination of this effect would require that enough carcass material be available for aging rails or detailed studies tracking rail chicks from the time of hatching until dispersal.

Passerines

There were 25 passerine species collected in this study. All were common species with wide geographic distribution. The limited powerline mortality observed in this study would be unlikely to significantly adversely affect any passerine species.

Raptors

Three raptors, a black-shouldered kite, a barn owl, and a short eared owl, were collected during the study. This level of mortality of one raptor per year appears unlikely to adversely affect the population levels of any raptor species.

Gulls and Terns

There were high numbers of powerline crossings for several gull and tern species, but powerline mortality associated with these species was low (Table 5-1). The California gull had the highest number of losses with 16 mortalities found during the three-year study. This mortality level is unlikely to adversely affect the population levels of gull or tern species.

Bats

Only one bat, a hoary bat, was collected during the 3-year study. Therefore, bat populations are extremely unlikely to adversely affected by powerline mortality within the study area.

EFFECTS OF WEATHER AND LOCAL BIRD POPULATION SIZE ON BIRD MORTALITY

Several methodological problems became apparent during the multiple regression analysis and could not be resolved within the scope of this study. Actual flight survey or pond census data were used as density estimates, with linear interpolation providing estimates for search days on which no surveys were performed. In previous reports estimates were provided by smoothed curves fitted to census data. The latter estimates are probably a better approximation of seasonal densities, since the former overemphasize short-term fluctuations in numbers.

Analyzing data by bird group did not increase the resolution of multiple regression models. Decreased sample sizes explain part of this effect. The results also suggest that the interaction between weather variables and mortality vary from year to year. Thus, combining data for several years may actually obscure the relationships between weather and mortality.

The absence of a correction for seasonal trends in weather makes results difficult to interpret. This is particularly true for tidal variables with complex daily and seasonal variation. Autoregressive analysis is needed to clarify these relationships.

Despite these difficulties, several trends emerge. First of all, shorebird mortality does not seem affected by weather. The presence of shorebirds in the area is determined by Leslie Salt's management of Pond #1. When Leslie Salt pumps from this pond, mud flats are exposed and used by shorebirds. When pumping is suspended, the pond fills and the mud flats are covered. Typically, Leslie Salt pumps in the summer and fall. In 1989, Pond 1 filled by the end of October. In 1990, it filled in early December. In 1989 and 1990 fall weather was mostly dry and mild, thus it is not surprising that shorebird mortality showed little relation to weather.

The relation of duck mortality to weather is unclear. Tide variables enter strongly into the models, but may only reflect seasonality. Two relationships appear fairly consistently. First, mortality decreases with higher winds on the preceding day (see Table G-4, variable EWWIND_M). Secondly, variables such as rain, barometric pressure, and north-south wind components tend to appear in the models developed for this report and for previous reports. This may indicate a response to unsettled weather, and the need for a more focused analysis. Weather in the past two winters has been anomalous. During the month of March 1991, which saw most of the year's rainfall, no dead ducks were found.

The analysis of weather and mortality for separate groups resulted in discovering one relationship which does not appear when the groups are combined. Landbirds show increased mortality with higher peak wind gusts during the previous day. One possible explanation is that the smaller size of landbirds in this study made them susceptible to being blown into powerlines.

Section 6

MITIGATION ALTERNATIVES

The approved methodology requires an investigation of practical mitigation measures if the COE determines that a "moderate or uncertain" level of bird mortality was attributable to the transmission line. Without stating the need for mitigation measures here, we offer the following alternative methods to reduce bird mortality based on current state-of-the-art approaches.

AERIAL MARKERS

Most research on the effectiveness of aerial markers on transmission lines to reduce bird mortalities has focused on whooping cranes and sandhill cranes. However, the findings from those studies should be somewhat applicable to other species of birds. Orange airway markers placed on distribution lines have been reported to eliminate sandhill crane mortality (Rigby 1978, Littlefield pers. comm. 1986). Other studies have reported that aerial marker systems reduced crane mortality by approximately 50% (Beaulaurier 1981, Brown et al. 1985). Willdan Associates (1981) suggested that reduction in bird collisions may have been partly due to decreased habitat use near marked lines.

Installation of aerial markers on conductors to increase visibility appears to be an effective method of mitigating bird collision mortality. Two or three 9- to 21-inch airway markers per span have been effective in deterring birds from power lines (Lee 1983, Keller and Rose 1984, Littlefield pers. comm. 1986). Installation of 30 cm yellow aviation balls with a vertical black stripe onto static wires significantly affected sandhill crane behavior and effectively reduced collisions (Morkill and Anderson 1991). Yellow-green luminescent markers have the greatest detectability under poor light conditions (Beaulaurier 1981).

A variety of markers have been tried, including airway marker balls, colored ribbons, tape, spiral vibration dampers, and swinging plates. Beaulaurier (1981) has reviewed a number of alternatives including net-type polyethylene tubing used by Hokkaido Electric Company in Japan. Jim Lewis, the USFWS whooping crane coordinator, suggests using orange and yellow aerial markers or brightly colored spiral wind deflectors (pers. comm. 1986). Yellow spiral vibration dampers and swinging yellow fiberglass plates with a horizontal black stripe have been used to mark powerlines in Colorado. Both have proved effective in reducing waterfowl mortality, however, some engineering problems (line chafing) has been observed with the swinging plates. The spiral vibration dampers and the fiberglass plates have reduced collisions by 48%. It is not yet known which of the two markers is more effective (Brown and Drewien 1991).

The use of aerial markers on powerlines is a very sensitive issue within the power industry for many reasons. Most do not favor markers because they (1) create targets for illegal shooting and thus dangerously jeopardize the reliability of the transmission or distribution lines, (2) hamper routine visual inspection of conductors, (3) are a noticeable eyesore where they can be viewed by the public, (4) alter the wind loading on the conductors and set up vibrations that the conductors may not have been designed for, and (5) produce radio frequencies at high voltages that may cause unacceptable interference with licensed broadcasts. Increased radio interference is a particular concern because it could adversely affect the nearby Naval Security Group Activity radio receiving facility at Skaggs Island.

TREE PLANTING

An alternative to aerial markers would be the planting of a row of tall trees adjacent to the transmission line at a sufficient distance to avoid future conflict with the conductors when the trees reach maturity. Birds would gain sufficient altitude to clear the trees, and thus surmount the conductors (Jaroslow 1979, Plunkett pers. comm. 1986). Desirable characteristics for trees include native species, compatibility with local climate and soil, rapid growth rate, evergreen foliage, and little or no maintenance. Inquiries to a number of horticulturists and the Soil Conservation Service resulted in few recommended tree species. Blue gum, casuarina, and tamarisk were suggested (eucalyptus trees currently thrive in several locations near the study area). These species fit all the specified criteria except they are exotics. No native trees were recommended.

OTHER ALTERNATIVES

The Navy studied undergrounding the powerline in its Environmental Assessment. It determined that undergrounding the powerline was impractical for engineering and economic reasons. The Navy proposed investigating burying a powerline of lower voltage in another location as mitigation for construction of the new high voltage powerline. This idea was rejected by Peggy Kohl, Office of Ecological Services, USFWS, when proposed by Douglas Pomeroy of the Navy. The Navy proposed this option in an interagency meeting including the COE, Navy, USFWS Office of Ecological Services, and USFWS San Francisco Bay National Wildlife Refuge, prior to receipt of the Letter of Permission to construct this project (Pomeroy pers. comm. 1991).

The Navy evaluated several alternative routes for the powerline during development of the Environmental Assessment. It determined that the route chosen was the most appropriate route for the powerline. Habitat alteration to discourage bird use in an area can reduce collisions, but it often conflicts with established land use. Conductor enlargement (to increase visibility) is possible, but expensive, and may be impractical. After Year 1 data collection was complete, the Navy proposed conducting off-site mitigation such as wetlands restoration or improvement instead of spending additional funds for more studies. The Navy presented this idea in a September 1989 interagency meeting with the COE, USFWS Ecological Services Office, and CDFG.

Mike Long, Office of Ecological Services, USFWS, advised the Navy that USFWS still wanted the three year monitoring effort to occur rather than off-site mitigation. Therefore, the monitoring effort was completed. The Navy stated in interagency meetings with the COE and the USFWS prior to receiving the Letter of Permission to construct the powerline, that if given the authorization to build the transmission line, its subsequent removal would not be considered practicable mitigation (Pomeroy pers. comm. 1991).

Section 7

ACKNOWLEDGMENTS

We are grateful to the many people who helped in this study. We appreciate the comments and advice on the overall study design by Doug Pomeroy (U.S. Navy), Richard Williams, and Jack Allen. Elaine Wong and Jim Park provided helpful coordination of the study with PG&E's Redwood Region. We are grateful to Christine Chan, Lisa Kahn, Lisa Kerr, and Elizabeth Lucas for their assistance with the mortality searches. We especially thank Jocelyn Aycrigg, Steve Cannata, Robert Mulder, and Tiffany Yuen not only for helping with mortality searches but also with data management, feather identification, and assisting during various bias studies. We appreciate the expert help in feather identification by Doug Bell, Julia Smith, and Pamela Williams (University of California, Berkeley), and we thank Dave Jessup and David Hunter (CDFG) and Bradford Barr (U.C., Davis) for performing necropsies. We are grateful to John Takekawa and Louise Accurso (USFWS) for providing us with waterfowl abundance data and Gary Page (PRBO) for providing us with shorebird census figures. We thank Dave DeSante, Kevin Guse, and Joan Humphrey for performing most of the day flight pattern surveys. Doug Bell and Julia Smith deserve special thanks for performing the difficult night flight pattern surveys. We appreciate Helen Green, Steve Laymon, and Chris Schneider filling in during day and night surveys. Ron Sousa and Roger Cunningham provided very reliable and accurate weather data throughout the study. We thank John Buchholz, Shirley Dexter, and Sue Grubb for preparing the figures. Jennifer Armstrong provided cheerful word processing support.

Section 8

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Appendix A. Common and scientific names.

Common Name	Scientific Name	Common Name	Scientific Name
Birds			
Red-throated loon	Gavia stellata	House wren	Troglodytes aedon
Pied-billed grebe	Podilymbus podiceps	Ruby-crowned kinglet	Regulus calendula
Horned grebe	Podiceps auritus	Western bluebird	Sialia mexicana
Eared grebe	Podiceps nigricollis	Hermit thrush	Catharus guttatus
Western grebe	Aechmophorus occidentalis	Varied thrush	Ixoreus naevius
American white pelican	Pelecanus erythrorhynchos	American pipit	Anthus spinoletta
Double-crested cormorant	Phalacrocorax auritus	European starling	Sturnus vulgaris
Brandt's cormorant	Phalacrocorax penicillatus	Orange-crowned warbler	Vermivora celata
Great blue heron	Ardea herodias	Yellow warbler	Dendroica petechia
Great egret	Casmerodius albus	Townsend's warbler	Dendroica townsendi
Snowy egret	Egretta thula	Wilson's warbler	Wilsonia pusilla
Black-crowned night heron	Nycticorax nycticorax	Rufous-sided towhee	Pipilo erythrophthalmus
Green-winged teal	Anas crecca	Chipping sparrow	Spizella passerina
Mallard	Anas platyrhynchos	Savannah sparrow	Passerculus sandwichensis
Northern pintail	Anas acuta	Song sparrow	Melospiza melodia
Cinnamon teal	Anas cyanoptera	Lincoln's sparrow	Melospiza lincolnii
Gadwall	Anas strepera	Golden-crowned sparrow	Zonotrichia atricapilla
American wigeon	Anas americana	White-crowned sparrow	Zonotrichia leucophrys
Canvasback	Aythya valisineria	Dark-eyed junco	Junco hyemalis
Greater scaup	Aythya marila	Red-winged blackbird	Agelaius phoeniceus
Lesser scaup	Anthya affinis	Western meadowlark	Sturnella neglecta
Common goldeneye	Bucephala clangula	Brewer's blackbird	Euphagus cyanocephalus
Bufflehead	Bucephala albeola	Purple finch	Carpodacus purpureus
Ruddy duck	Oxyura jamaicensis	House finch	Carpodacus mexicanus
Black-shouldered kite	Elanus caeruleus		
American kestrel	Falco sparverius		
Peregrine falcon	Falco peregrinus	Mammals	
California quail	Callipepla californicus	Hoary bat	Lasiurus cinereus
Virginia rail	Rallus limicola		
Sora	Porzana carolina	Plants	
American coot	Fulica americana	Radish	Raphanus spp.
Black-bellied plover	Pluvialis squatarola	Mustard	Brassica spp.
Semipalmated plover	Charadrius semipalmatus	Salt grass	Distichlis spp.
Killdeer	Charadrius vociferus	Pickleweed	Salicornia subterminalis
Black-necked stilt	Himantopus mexicanus	Blue gum	Eucalyptus globulus
American avocet	Recurvirostra americana	Tamarisk	Tamarix aphylla
Willet	Catoptrophorus semipalmatus	Fremont cottonwood	Populus fremontii
Wandering tattler	Heteroscelus incanus		
Whimbrel	Numenius phaeopus		
Long-billed curlew	Numenius americanus		
Marbled godwit	Limosa fedoa		
Ruddy turnstone	Arenaria interpres		
Sanderling	Calidris alba		
Western sandpiper	Calidris mauri		
Least sandpiper	Calidris minutilla		
Dunlin	Calidris alpina		
Short-billed dowitcher	Limnodromus griseus		
Long-billed dowitcher	Limnodromus scolopaceus		
Red-necked phalarope	Phalaropus fulcaria		
Bonaparte's gull	Larus philadelphia		
Mew gull	Larus canus		
Ring-billed gull	Larus delawarensis		
California gull	Larus californicus		
Herring gull	Larus argentatus		
Western gull	Larus occidentalis		
Caspian tern	Sterna caspia		
Rock dove	Columba livia		
Mourning dove	Zenaida macroura		
Common barn owl	Tyto alba		
Short-eared owl	Asio flammeus		
Western flycatcher	Empidonax difficilis		
Black phoebe	Sayornis nigricans		

MARE ISLAND TRANSMISSION LINE BIRD MORTALITY DATA SHEET

Location	Date			Time		Seacher		Sky		Temp (°C)		Beginning Wind		End Wind		Comments
	Mo	Da	Yr	Beg.	End	1	2	Beg.	End	Beg.	End	Speed	Dir.	Speed	Dir.	
1	3 4	5 6	7 8	10 11 12 13	15 16 17 18	20 21 22	23 24 25	27 28	30 31	33 34	36 37	39	41 42	44	46 47	49

Specimen Number	Transect	Date			Between Poles		Distance from Pole		Distance from Center				Species Code	Species	Condition	Collected	Time of Collection	Detectability Code	Flagged	Photographed	Necropsy	Comments
		Mo	Da	Yr	A	B	A	B	N	S	E	W										
1 2 3 4	6	8 9	10 11	12 13	15 16	17 18	20 21 22	23 24 25	27 28	29 30	31 32	33 34	36 37 38		40 41	43	45 46 47 48	50	52	54	56	

BIRD MORTALITY DATA SHEET INSTRUCTIONS

column	standard operating procedures
LOCATION	Transect: (1 - hay field, 2 - salt pond, 3 - 2 spans north of Transect 2, 4 - western-most levee of salt pond)
DATE	Date of data acquisition: Numeric form; e.g. 8/14/88.
TIME	Military time at beginning and end of data collection; e.g. 1840.
SEARCHERS	Initials of data collector(s); e.g. RJR. If more than 2 searchers, note additional initials in "comments."
SKY	Sky conditions: Observed at beginning and end of data collection. (01 - clear, 02 - partly cloudy, 03 - overcast, 04 - fog, 05 - drizzle, 06 - rain, 07 - snow, 08 - hail, 09 - sleet, 10 - hazy).
TEMP	Temperature taken in the shade at beginning and end of data collection, recorded in C; e.g. 37.
WIND	Wind description: Observed at beginning and end of data collection. Use 2-letter compass bearing for direction, e.g. NW. Code for wind speed. (1 - <1 MPH, calm, smoke rises vertically; 2 - 1-3 MPH, direction of smoke shown by direction of smoke drift; 3 - 4-7 MPH, wind felt on face, leaves rustle; 4 - 8-12 MPH, leaves in constant motion, wind extends light flag; 5 - 13-18 MPH, raises dust & loose paper, moves small branches; 6 - 19-24 MPH, small trees sway, crested wavelets form on land waters; 7 - 25-31 MPH, moves large branches, whistling heard in telegraph wires; 8 - 32-38 MPH, moves whole trees; 9 - 39-46 MPH, breaks twigs off trees, generally impedes progress)
SPECIMEN NUMBER	Specimen number: Assign each specimen a consecutive specimen number.
BETWEEN POLES	Record the numbers of the poles on either side of the specimen's location for Transects 1-3. Assign the northern-most or western-most pole number to pole A. Leave blank for Transect 4.
DISTANCE FROM POLE	For Transects 1-3 measure the distance in meters from the specimen's location to the nearest pole, and record in the appropriate column (A or B). For Transect 4 record under column A the distance from the specimen to the northern-most transmission line.
DISTANCE FROM CENTER	Distance from center: For Transects 1-3, measure the distance in meters from the specimen's location to the center transmission line. For Transect 4, measure the distance in meters from the specimen's location to the center of the flagged line running north-south perpendicular to the transmission line. Record under the column appropriate to the location from the center line, e.g. 14 meters west of the line would be recorded under the "W" column as 14.
SPECIMEN LENGTH	Length of specimen in centimeters.
SPECIMEN WIDTH	Width of specimen in centimeters.
COVER	% of specimen not visible when looking straight down on it.
HEIGHT 1	Average vegetation height within a one-meter radius of the specimen. Record in centimeters.
DENSITY 1	Average percentage of ground covered within a one-meter radius of the specimen.
HEIGHT 3	Average vegetation height within a three-meter radius of the specimen. Record in centimeters.
DENSITY 3	Average percentage of ground covered within a three-meter radius of the specimen.
CONDITION	Condition of specimen: (01 - injured, 02 - dead and intact, 03 - partially decomposed/eaten, 04 - feather spot and bones, 05 - feather spot only, 06 - bones only (general), 07 - wing, 08 - skull, 09 - leg or foot only, 10.
DETECTABILITY	Detectability Code: 1 - Extremely difficult to detect; however the finding still qualifies as a mortality. A specimen at this level of detectability is difficult to see when you are looking directly at it. Note that small, well-camouflaged birds could be assigned this code, as well as small camouflaged feather spots. 2 - Very difficult to detect; you need to look nearly directly at the specimen. However, once found, the specimen is not very difficult to see. 3 - Easy to detect, but not until you are fairly close to it (3-5m). 4 - Attracts your attention. This might include a wounded bird moving around, or a giant feather spot left by a pelican or egret.
TIME OF COLLECTION	Military time that specimen found, e.g. 1920.
PHOTOGRAPHED	Photographed specimen: Y - yes, N - no.
FLAGGED	Flagged feather spot: Y - yes, N - no.

Additional information may be noted under "Comments." If you need more room, write on the back of the page, and label comments with specimen number.

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In Years 2 and 3 we also recorded the following vegetation and specimen characteristics in an attempt to discover a more objective method of categorizing the detection class of the specimens: average percent cover density within a 1- and 3-m radius from the specimen center, average vegetation height within a 1- and 3-m radius from the specimen center, percent of specimen covered by vegetation or other objects, and length and width of the specimen. In addition, beginning November 29, 1989, we recorded a subjective rating of the specimen's contrast to the immediate area. These characteristics are not used for data analysis in this report.

Table C-1. Necropsy summary: Number of birds by species and cause of death (includes live, injured birds). Birds were found during mortality searches in the Mare Island bird study area during the 88/89, 89/90 and 90/91 seasons.

Species	Cholera	Gunshot Wounds	Live Injured	Malnu-trition	Non-trauma[a]	Suspect Trauma	Trauma	Unknown	Transect Totals HF	SP	C-A	C-B	Total
88-89 American white pelican						1					1		1
89-90 Double-crested cormorant						1			1				1
88-89 Mallard		1							1				1
88-89 Cinnamon teal		1				1				2			2
88-89 Greater scaup						1		1		2			2
89-90 Greater scaup							1		1				1
88-89 Ruddy duck	34[b]	3			1[c]	1	4	14[d]		53		4	57
89-90 Black-shouldered kite		1							1				1
88-89 American kestrel								1			1		1
89-90 Black rail								1	1				1
90-91 Black rail							1			1			1
89-90 Sora							1		1				1
88-89 American coot						1	1			2			2
89-90 American coot			1[e]							1			1
90-91 American coot							1			1			1
88-89 Black-bellied plover							2	2	1	3			4
89-90 Black-bellied plover							1[f]				1		1
90-91 Black-bellied plover							9[e]		1	8			9
88-89 Sanderling								1		1			1
90-91 Semipalmated plover								1		1			1
88-89 Western sandpiper			3[g]		1[h]		4	3	1	9	1		11
89-90 Western sandpiper			2[hg]			4	4		5	3	2		10
90-91 Western sandpiper						1	3[h]	1	1	3	1		5
89-90 Least sandpiper							1				1		1
88-89 Dunlin							3		1	2			3
89-90 Dunlin							1			1			1
90-91 Dunlin							1[eh]	1		1	1		2
90-91 Short-billed dowitcher			1[g]				1[e]			2			2
88-89 Red-necked phalarope			3[gi]							3			3
89-90 Red-necked phalarope			1[g]							1			1
90-91 Red-necked phalarope			1[g]							1			1
90-91 Ring-billed gull								1		1			1
88-89 California gull								3		2	1		3
89-90 California gull			1[g]					1	1	1			2
90-91 California gull								1		1			1
88-89 Herring gull							1			1			1
89-90 Caspian tern				1						1			1
90-91 Mourning dove							1		1				1

Table C-1 (cont).

Species	Cholera	Gunshot Wounds	Injured	Malnu-trition	Non-trauma	Suspect Trauma	Trauma	Unknown	Transect Totals HF	SP	C-A	C-B	Total
89-90 Western flycatcher								1	1				1
90-91 Black phoebe							1[e]			1			1
88-89 Ruby-crowned kinglet								1	1				1
90-91 Ruby-crowned kinglet								1	1				1
90-91 Hermit thrush							1		1				1
88-89 American pipit							1		1				1
89-90 American pipit							1		1				1
90-91 European starling							1		1				1
89-90 Orange-crowned warbler						1				1			1
90-91 Townsend's warbler								1	1				1
89-90 Wilson's warbler								1	1				1
90-91 Wilson's warbler							1	1	2				2
88-89 Savannah sparrow							4	2	6				6
89-90 Savannah sparrow						4	1	2	5	2			7
90-91 Savannah sparrow							6[e]	2[h]	4	3	1		8
88-89 Lincoln's sparrow						1	1		2				2
89-90 Lincoln's sparrow						1		1	1	1			2
89-90 Golden-crowned sparrow							1		1				1
90-91 Golden-crowned sparrow	1								1				1
88-89 White-crowned sparrow						1	1		1	1			2
89-90 White-crowned sparrow						2	1		3				3
88-89 G- or W-crowned sparrow						1			1				1
88-89 Sparrow species								1	1				1
89-90 Dark-eyed junco						1			1				1
88-89 Red-winged blackbird				1		1	2		4				4
89-90 Red-winged blackbird							3	1[h]	2	1	1		4
88-89 Western meadowlark							1	1	1	1			2
89-90 Western meadowlark			1				2		2	1			3
90-91 Western meadowlark							1[e]		1				1
88-89 Brewer's blackbird							1		1				1
89-90 Brewer's blackbird			1[e]			1[f]			2				2
90-91 Brewer's blackbird							1		1				1
90-91 House finch								1	1				1
88-89 Bird species					1[c]			7[ch]		3	3	2	8
Total 88-89	34	5	6	1	3	9	26	37	23	85	7	6	121
Total 89-90	0	1	7	1	0	15	18	8	30	15	5	0	50
Total 90-91	1	0	2	0	0	1	29	11	17	24	3	0	44
Total Hay Field and Salt Pond	34	6	13	2	0	24	69	46	70	124			194

[a] Although the specific cause of death could not be determined, these birds were in good enough condition to be able to rule out trauma.

Table C-1 (cont).

[b] 28 of these birds were not in suitable condition for necropsy. All except one were picked up on 2/9/89 along the western edge of the salt pond where six birds were found that tested positive for cholera. One bird found in comparison transect B.

[c] Bird(s) found in comparison transect B.

[d] Two birds found in comparison transect B.

[e] Head injury.

[f] Suspect predation.

[g] Wing injury.

[h] Bird(s) found in comparison transect A.

[i] One bird with unknown injuries.

Table D-1. Results of search bias tests conducted within the Mare Island Transmission Line Study Area during Years 1, 2, and 3.

Date	Nearest Pole	Detect Level	Found During Routine Search	Found After Routine Search	Description
8/10/88[1]	various[2]	N/A	22/37	Yes	whole birds
			27/37	Yes	
10/20/88	various[2]	N/A	1/6	1	whole birds
1/19/89	various[2]	1	0/5	5	feather spots and bones
		2	1/5	4	feather spots and bones
4/13/89	1	3	Yes	N/A	whole bird
	4	3	Yes	N/A	feather spot
	7	3	Yes	N/A	feathers and bones
	9	3	Yes	N/A	whole bird
	11	3	Yes	N/A	feather spot
	13	3	Yes	N/A	whole bird
	13	3	Yes	N/A	whole bird
	18	3	Yes	N/A	feathers and bones
	24	3	Yes	N/A	whole bird
	39	3	Yes	N/A	whole bird
	44	2	No	Yes	whole bird
	45	2	Yes	N/A	whole bird
	900 m	2	Yes	N/A	feather spot
	1050 m	2	No	Yes	feather spot
8/17/89	2	3	Yes	N/A	whole bird
	5	3	Yes	N/A	whole bird
	6	2	No	Yes	wing
	8	2	No	No	wing
	9	3	Yes	N/A	foot & feathers
	11	3	No	No	wing
	12	2	Yes	N/A	wing
	14	3	No	Yes	feather spot
	16	3	Yes	N/A	feather spot
	17	1	No	Yes	wing
11/16/89	2	3	Yes	N/A	left wing of sandpiper
	4	3	Yes	N/A	right wing of sandpiper
	5	2	No	Yes	foot and feathers of coot
	8	3	Yes	N/A	feathers of shorebird
	10	2	No	No	whole b-b plover
	12	1	No	Yes	whole b-b plover
	13	3	No	Yes	whole mallard
	14	1	No	Yes	feathers of shorebird
	15	3	No	No	wing of mallard
	17	3	Yes	N/A	feathers of mallard
2/15/90	4	2	No	Yes	duck tail feathers
	5	2	No	Yes	duck tail feathers
	6	3	No	Yes	duck wing
	7	3	Yes	N/A	duck tail feathers
	9	3	Yes	N/A	duck body feathers
	10	2	No	Yes	duck body feathers
	11	3	Yes	N/A	duck wing
	12	2	No	Yes	duck tail feathers
	14	3	Yes	N/A	duck wing
	15	2	No	Yes	duck body feathers
	16	3	Yes	N/A	duck wing
	17	3	Yes	N/A	duck wing

Table D-1 (cont).

Date	Nearest Pole	Detect Level	Found During Routine Search	Found After Routine Search	Description
5/9/90	1	3	Yes	N/A	feather spot
	3	2	No	Yes	feather spot
	4	3	Yes	N/A	feather spot
	6	3	Yes	N/A	feather spot
	7	4	Yes	N/A	feather spot and bones
	8	2	No	Yes	feather spot
	11	3	Yes	N/A	whole bird
	12	2	No	Yes	wing
	13	2	No	Yes	feather spot
	16	2	Yes	N/A	whole bird
8/15/90	A	1	No	No	feather spot
	1	1	No	Yes	feather spot
	1	1	No	Yes	feather spot
	3	1	No	Yes	feather spot
	3	2	No	Yes	feather spot
	4	1	No	Yes	feather spot
	4	1	No	Yes	feather spot
	5	1	No	Yes	feather spot
	5	1	No	Yes	feather spot
	6	2	No	Yes	wing
	7	1	No	No	feather spot
	7	1	No	Yes	whole bird
	7	1	No	Yes	feather spot
	7	1	No	Yes	feather spot
	8	1	No	No	feather spot
	9	1	No	Yes	whole bird
	10	1	No	Yes	whole bird
	11	2	No	Yes	feather spot
	11	1	No	Yes	feather spot
	12	1	No	Yes	feather spot
	13	1	No	Yes	whole bird
	13	1	No	Yes	feather spot
	13	1	No	No	feather spot
	15	1	No	Yes	feather spot and bones
	16	1	No	No	feather spot

[1] Two teams each searched for the same 37 birds.
[2] Specific locations are not available.

Table E-1. Scavenger studies: Percentage of birds remaining under transects after the date of placement.

Date of Placement		Number of Days Following Placement 1	2	3	4	5	6	7	8	9	10
Year 1											
10/25/88											
n[1]=14	Hay Field	79	57	50	36						
n=10	Salt Pond	100	57	50	36						
3/2/89											
n=13	Hay Field	85	N/A	N/A	31	23	8	8	8		
n=10	Salt Pond	80	N/A	N/A	50						
n=10	CTB	90	N/A	N/A	50	50	40				
5/17/89											
n=13	Hay Field	100	100	100	100	100	100	100	100	85	
n=9	Salt Pond	100	100	100	100	100	100	100	100	100	
n=4	CTB	75	75	50	50	50	50	50	50	50	
Year 2											
8/15/89											
n=10	Hay Field	90	70	70	60	60	50	40	30	20	20
n=10	Salt Pond	90	90	80	80	80	80	80	80	80	80
n=5	CTB	40	40	40	20	20	20	20	0	0	0
10/19/89											
n=10	Hay Field	60	60	50	50	50	50	50	50	40	
n=10	Salt Pond	89	56	56	56	56	44	44	44	44	
n=7	CTB	100	100	100	86	71	57	57	57	57	
1/4/90											
n=20	Hay Field	100	100	95	90	90	90	90	90	90	90
n=9	Salt Pond	67	67	56	56	56	56	56	56	33	33
n=6	CTB	100	100	100	83	83	83	83	83	83	83
5/15/90											
n=20	Hay Field	95	95	80	65	65	65	60	50	50	
n=9	Salt Pond	100	100	78	78	78	78	78	78	78	
n=6	CTB	83	83	83	83	83	83	83	83	83	
Year 3											
8/21/90											
n=20	Hay Field	90	65	55	35	30	30	25	15	15	15
n=9	Salt Pond	100	89	89	89	67	67	67	56	56	56
n=8	CTB	88	75	75	75	50	50	50	50	50	50
10/22/90											
n=20	Hay Field	85	65	55	45	45	45	30	25	25	25
n=9	Salt Pond	67	67	67	44	44	44	44	44	44	44
n=8	CTB	63	50	38	25	25	25	25	25	25	25
1/21/91											
n=20	Hay Field	100	75	45	20	15	5	0	0	0	0
n=9	Salt Pond	100	56	9	9	0	0	0	0	0	0
n=8	CTB	88	88	63	25	13	13	13	13	13	13
4/29/91											
n=20	Hay Field	95	90	90	85	85	75	75	75	75	75
n=8	Salt Pond	100	88	63	63	63	63	63	63	38	25
n=8	CTB	100	75	75	75	63	50	50	50	50	50

[1]n=sample size

Table F-1. Proportion of area that can be searched by span and cell location within the Mare Island Transmission line study area during Year 3. See Figure G-1 for layout of cells.

	Cell[1]			
Pole[2]	A	B	C	D
Salt pond and Control A 08/11/88 - 03/02/89				
B	1	.92	.88	1
A	1	1	1	1
1	1	1	1	1
2	1	1	1	1
3	1	1	1	1
4	1	1	1	1
5	1	1	1	1
6	1	1	1	1
7	1	1	1	1
8	1	1	1	1
9	1	1	1	1
10	1	1	1	1
11	1	1	1	1
12	1	1	1	1
13	1	1	1	1
14	1	1	1	1
15	1	1	1	1
16	1	1	1	1
17	1	1	1	1
Salt pond and Control A 03/02/89 - 05/03/89				
B	.96	.92	.88	.01
A	.96	.92	.88	.01
1	1	.88	.88	.01
2	1	.88	.88	.01
3	.96	.76	.9	.01
4	1	.9	.95	.01
5	1	.8	1	.01
6	1	.8	.95	.01
7	1	.8	.95	.01
8	.96	.7	.95	.01
9	.96	.7	.95	.01
10	1	.68	.95	.01
11	.92	.6	1	.01
12	.92	.6	.9	.01
13	.96	.64	1	.8
14	.76	.55	.85	.36
15	.6	.6	.75	.36
16	.84	.6	.7	.36
17	.64	.6	.7	.36
Salt pond and Control A 05/03/89 - 06/01/89				
B	.96	.92	.88	.01
A	.96	1	.88	.01
1	1	1	.88	.01
2	1	1	.88	.01
3	.96	1	.9	.01
4	.96	1	.95	.01
Salt pond and Control A 05/03/89 - 06/01/89 (cont)				
5	1	1	1	.01
6	1	1	.95	.01
7	1	1	.95	.01
8	.96	1	.95	.01
9	.96	1	.95	.01
10	1	1	.95	.01
11	.92	1	1	.01
12	.92	1	.9	.01
13	.96	1	1	.8
14	.76	1	.85	.36
15	.6	1	.75	.36
16	.84	1	.7	.36
17	.64	1	.7	.52
Hay field 08/11/88 - 03/02/89				
18	.64	1	1	1
19	.64	1	1	1
20	.64	1	1	1
21	.64	1	1	1
23	.64	1	1	1
22	.88	1	1	1
24	1	1	1	1
25	.68	1	1	1
26	.01	1	1	1
27	.01	1	1	1
28	.01	1	1	1
29	.04	1	1	1
30	.04	1	1	1
31	.04	1	1	1
32	.16	1	1	1
33	.12	1	1	1
34	.16	1	1	1
35	.12	1	1	1
36	.12	1	1	1
37	.12	1	1	1
38	.32	1	1	1
39	.32	1	1	1
40	.32	1	1	1
41	.24	1	1	1
42	.24	1	1	1
43	.24	1	1	1
44	.24	1	1	1
45	.24	1	1	1
46	.16	1	1	1
47	.16	1	1	1
48	.16	1	1	1
49	.16	1	1	1
50	.01	1	1	1
Hay field 08/11/88 - 03/02/89 (cont)				
51	.01	1	1	1
52	.01	1	1	1
53	.01	1	1	1
54	.01	1	1	1
55	.01	1	1	1
56	.01	1	1	1
57	.01	1	1	1
Hay field 03/02/89 - 04/06/89				
18	.64	1	1	1
19	.64	1	1	1
20	.64	1	1	1
21	.64	1	1	1
22	.64	1	1	1
23	.88	1	1	1
24	1	1	1	1
25	.18	.5	.5	.5
26	.01	.5	.5	.5
27	.01	.5	.5	.5
28	.01	.5	.5	.5
29	.04	.5	.5	.5
30	.04	.5	.5	.5
31	.04	.5	.5	.5
32	.1	.5	.5	.5
33	.08	.5	.5	.5
34	.14	.5	.5	.5
35	.11	.5	.5	.5
36	.11	.5	.5	.5
37	.11	.5	.5	.5
38	.16	.5	.5	.5
39	.16	.5	.5	.5
40	.16	.5	.5	.5
41	.2	.6	.6	.6
42	.2	.6	.6	.6
43	.2	.6	.6	.6
44	.2	.6	.6	.6
45	.2	.6	.6	.6
46	.16	.6	.6	.6
47	.16	.6	.6	.6
48	.16	.6	.6	.6
49	.16	.6	.6	.6
50	.01	.8	.8	.8
51	.01	.8	.8	.8
52	.01	.8	.8	.8
53	.01	.8	.8	.8
54	.01	.8	.8	.8
55	.01	.8	.8	.8
56	.01	.8	.8	.8
Hay field 03/02/89 - 04/06/89 (cont)				
57	.01	.5	.45	.4
Hay field 04/06/89 - 06/01/89				
18	.64	1	1	1
19	.64	1	1	1
20	.64	1	1	1
21	.64	1	1	1
22	.64	1	1	1
23	.88	1	1	1
24	1	1	1	1
25	.68	1	1	1
26	.01	1	1	1
27	.01	1	1	1
28	.01	1	1	1
29	.04	1	1	1
30	.04	1	1	1
31	.04	1	1	1
32	.16	1	1	1
33	.12	1	1	1
34	.16	1	1	1
35	.12	1	1	1
36	.12	1	1	1
37	.12	1	1	1
38	.32	1	1	1
39	.32	1	1	1
40	.32	1	1	1
41	.24	1	1	1
42	.24	1	1	1
43	.24	1	1	1
44	.24	1	1	1
45	.24	1	1	1
46	.16	1	1	1
47	.16	1	1	1
48	.16	1	1	1
49	.16	1	1	1
50	.01	1	1	1
51	.01	1	1	1
52	.01	1	1	1
53	.01	1	1	1
54	.01	1	1	1
55	.01	1	1	1
56	.01	1	1	1
57	.01	.5	.45	.4

Footnotes

[1] Cell A = 16-31 m south and west from the center conductor of the hay field and salt pond/control B transects, respectively;
Cell B = 1-15 m south and west from the center conductor of the hay field and salt pond/control B transects, respectively;
Cell C = 0-15 m north and east from the center conductor of the hay field and salt pond/control B transects, respectively; and
Cell D = 15-31 m north and east from the center conductor of the hay field and salt pond/control B transects, respectively.

[2] The span represented by this pole number is between that pole and the next highest pole number.

Table F-1. Proportion of area that can be searched by span and cell location within the Mare Island Transmission line study area during Year 3. See Figure G-1 for layout of cells.

Hay Field
7/18/90-5/30/91

Pole[2]	Cell[1] A	B	C	D
18	.64	1.0	.67[3]	NA[4]
19	.64	1.0	.67	NA
20	.64	1.0	.67	NA
21	.64	1.0	.67	NA
22	.64	1.0	.67	NA
23	.88	1.0	.67	NA
24	1.0	1.0	.67	NA
25	.18	1.0	.67	NA
26	.10	1.0	.67	NA
27	.10	1.0	.67	NA
28	.10	1.0	.67	NA
29	.10	1.0	.67	NA
30	.10	1.0	.67	NA
31	.10	1.0	.67	NA
32	.10	1.0	.67	NA
33	.08	1.0	.67	NA
34	.14	1.0	.67	NA
35	.11	1.0	.67	NA
36	.11	1.0	.67	NA
37	.11	1.0	.67	NA
38	.16	1.0	.67	NA
39	.16	1.0	.67	NA
40	.16	1.0	.67	NA
41	.20	1.0	.67	NA
42	.20	1.0	.67	NA
43	.20	1.0	.67	NA
44	.20	1.0	.67	NA
45	.20	1.0	.67	NA
46	.16	1.0	.67	NA
47	.16	1.0	.67	NA
48	.16	1.0	.67	NA
49	.16	1.0	.67	NA
50	.10	1.0	.67	NA
51	.10	1.0	.67	NA
52	.10	1.0	.67	NA
53	.10	1.0	.67	NA
54	.10	1.0	.67	NA
55	.10	1.0	.67	NA
56	.10	1.0	.67	NA
57	.10	1.0	.67	NA

Salt Pond
7/18/90-3/21/91

Pole	Cell A	B	C	D
B	1.0	.92	.88	1.0
A	1.0	1.0	1.0	1.0
01	1.0	1.0	1.0	1.0
02	1.0	1.0	1.0	1.0
03	1.0	1.0	1.0	1.0
04	1.0	1.0	1.0	1.0
05	1.0	1.0	1.0	1.0
06	1.0	1.0	1.0	1.0
07	1.0	1.0	1.0	1.0
08	1.0	1.0	1.0	1.0
09	1.0	1.0	1.0	1.0
10	1.0	1.0	1.0	1.0
11	1.0	1.0	1.0	1.0
12	1.0	1.0	1.0	1.0
13	1.0	1.0	1.0	1.0
14	1.0	1.0	1.0	1.0
15	1.0	1.0	1.0	1.0
16	1.0	1.0	1.0	1.0
17	1.0	1.0	1.0	1.0
3/27/91-5/2/91				
B	.95	.60	.95	.60
A	1.0	.65	.95	.60
01	1.0	.80	.95	.80
02	.95	.50	.95	.60
03	.95	.65	.95	.60
04	1.0	.60	1.0	.60
05	1.0	.60	1.0	.65
06	.95	.50	1.0	.50
07	.90	.50	.95	.50
08	.90	.60	1.0	.50
09	.85	.70	1.0	.50
10	.85	.80	.95	.50
11	.80	.50	1.0	.50
12	.85	.50	1.0	.70
13	.85	.80	1.0	.90
14	1.0	.80	.95	.75
15	.95	.70	1.0	.75
16	.95	.50	.95	.85
17	.90	.50	1.0	.95

Salt Pond
5/8/91-5/9/91[5]

Pole	Cell A	B	C	D
15	.95	.80	1.0	.75
16	.95	.75	.95	.85
17	.95	.75	1.0	.95
5/15/91-5/16/91				
15	1.0	.80	1.0	.75
16	1.0	.75	.95	.85
17	1.0	.75	1.0	.95
5/23/91-5/31/91				
B	.95	.60	.95	1.0
A	1.0	.65	.95	1.0
01	1.0	.80	.95	1.0
02	.95	.50	.95	1.0
03	.95	.65	.95	1.0
04	1.0	.60	1.0	1.0
05	1.0	.60	1.0	1.0
06	.95	.50	1.0	1.0
07	.90	.50	.95	1.0
08	.90	.60	1.0	1.0
09	.85	.70	1.0	1.0
10	.85	.80	.95	1.
11	.80	.50	1.0	1.
12	.85	.50	1.0	1.
13	.85	.80	1.0	1.
14	1.0	.80	.95	1.
15	.95	.70	1.0	1.
16	.95	.50	.95	1.
17	.90	.50	1.0	1.

[1]Cell A = 16-31 m south and west from the center conductor of the hay field and salt pond/CTB transects, respective
Cell B = 0-15 m south and west from the center conductor of the hay field and salt pond/CTB transects, respectivel
Cell C = 0-15 m north and east from the center conductor of the hay field and salt pond/CTB transects, respectively
Cell D = 16-31 m north and east from the center conductor of the hay field and salt pond/CTB transects, respectivel

[2]The span represented by this pole number is between that pole and the next highest pole number.

[3]See text for determination of Cell C value.

[4]Cell D not searched.

[5]Only spans with changes since the previous date are listed.

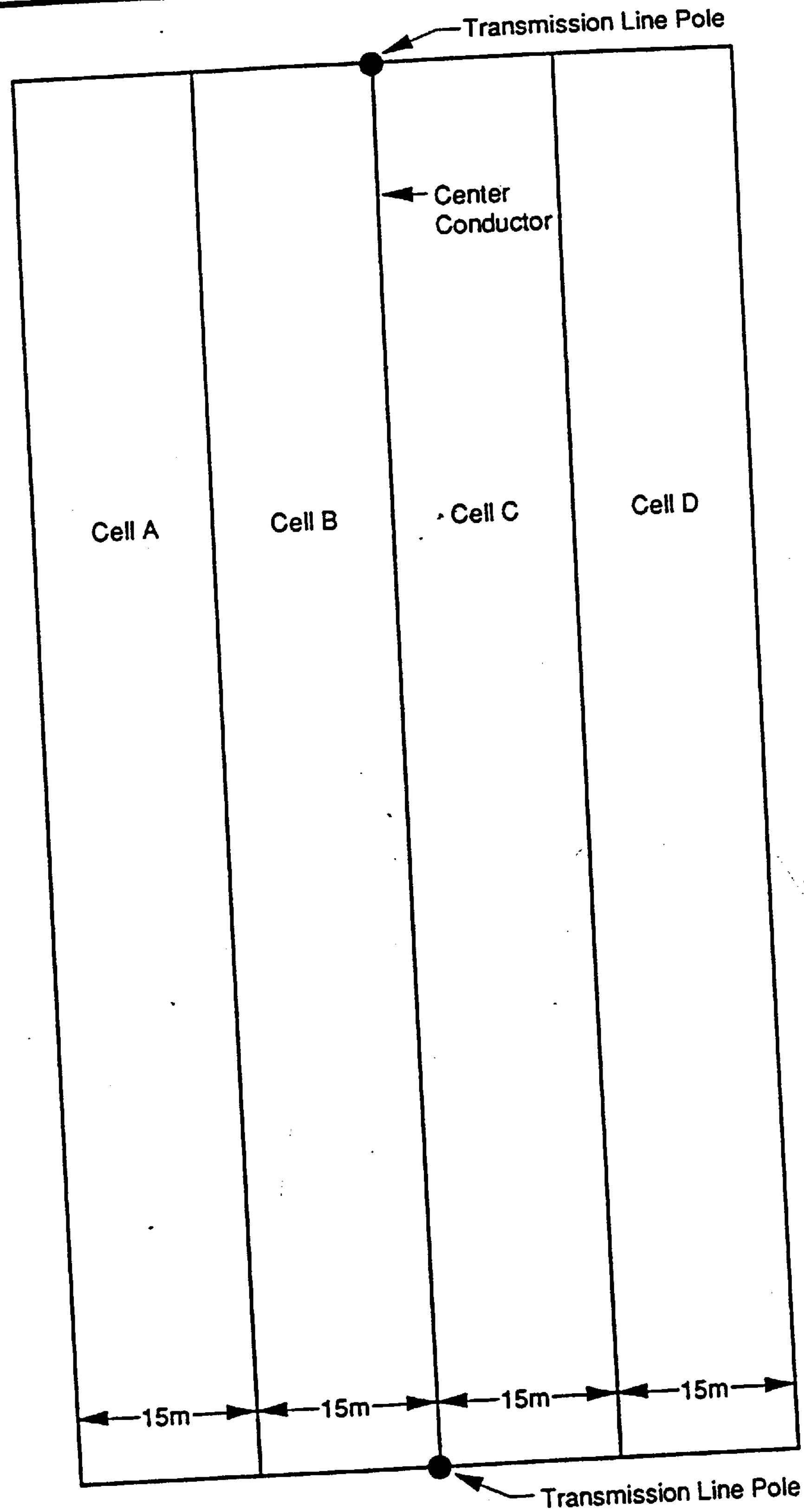


FIGURE F-1. Layout of cells for which the proportion of searchable area was estimated.

90-7-616

METHODS

WEATHER DATA COLLECTION

Weather data were collected at two locations. The first was the study site at the junction of Route 37 and the levee road (Figure 2-1 in text). An observer visited this site each morning during the periods September 19, 1988 to June 1, 1989; July 15, 1989 to June 9, 1990; and July 25, 1990 to June 19, 1991. These observations were generally made around sunrise on weekdays and within several hours of sunrise on weekends. Measurements taken included wind speed and direction, visibility, height of cloud cover, precipitation, and general weather conditions. In Year 3 an additional variable, percentage cloud cover, was recorded. Figure G-1 is the weather data sheet for Location 1. The weather measurements taken at this site and used in the analysis are included in Table G-1. Year 1 data were not used in this report.

Weather data were also obtained from a private weather station located near Slaughterhouse Point on the Napa River, approximately 8 km east of the site. This station collects the same local climatological data as official weather stations of the National Weather Service of the National Oceanic and Atmospheric Administration (NOAA). Data were available for the entire study period. Figure G-2 is a data sheet from this weather station. Weather measurements taken at this site and used in the analysis are included in Table G-1. Some of the measurements from the private weather station were not used in the analysis, as they were redundant.

NOAA publications also provided data on moon phase, tide times, and tide heights (NOAA 1988, NOAA 1989, NOAA 1990). Moon phase and tide variables used in this analysis are described in Table G-1.

WEATHER DATA ANALYSIS

We investigated the relation between weather variables and the level of bird mortality. The purpose of this analysis was to determine if factors that are suspected of contributing to bird mortality at powerlines (e.g., low visibility, moon phase, high winds, and precipitation) contributed significantly to the variation in mortality seen in this study. Univariate and multivariate analyses were performed using Release 6.03 SAS[1] software.

The primary technique used was multiple regression. Univariate methods were used for preliminary testing and transformation of variables to be included in the multiple regression model.

[1] SAS is a registered trademark of the SAS Institute, Inc., Cary, North Carolina.

MARE ISLAND T/L PROJECT
Daily Weather Report

Sheet ________of______

Dates________to______

Date	Time	Site		Wind Speed	Wind Dir.	Visibility			Cloud Height		Percent Cloud Cover	PPT	Comments
		spd	dir			from Napa Br.	from turn to north	from turn to east	ceiling (feet)	roof (feet)			

Site B -- near Napa Bridge
S -- Study Site

Wind Direction - N, NE, E, SE, S, SW, W, NW

Visibility from Napa Bridge

1 -- to Marin Hills
2 -- to the hay barn (2 mi)
3 -- to the near eucalyptus grove (0.8 mi)

Visibility from turn to north

1 -- to Napa Hills
2 -- to transmission line
3 -- less than 2. Enter # poles visible, including one close to fence.

Visibility from turn to east

1 - to Vallejo Hills
2 - to hay barn (eucalyptus grove - 1.8 mi)
3 - less than 2. Enter # poles visible.

Cloud ceiling

Estimated distance from ground to clouds

Cloud roof

Estimated height of top of fog, as seen from Napa Bridge

PPT = precipitation

Drizzle
Light
Moderate
Heavy

Pea soup, socked in
Smoggy
Crystal clear
Hazy
Drifting fog
Ground fog

Table G-1. Weather measurements taken on site (Location W1), taken at a nearby private weather station (Location W2), and from published data (P).

Measurement	Location	Description
Wind speed	W1	Velocity of wind in miles/hour
Wind direction	W1	N, NE, E, SE, S, SW, W, or NW
Visibility from: Napa Bridge Rte 37 & levee Rd to N Rte 37 & levee Rd to E	W1	This is measured on an ordinal scale from 1 (greatest visibility) to 3 (reduced visibility). See data sheet for details.
Cloud height ceiling	W1	Distance from ground to clouds
Cloud height roof	W1	Estimated height of top of fog. Variable was not used due to excessive missing values.
Precipitation	W1	An ordinal measure of rain as drizzle, light, moderate, heavy
Cloud Cover	W1	Percent cloud cover (1990-91 only)
Minimum temperature	W2	Lowest temperature in 24 hours
Maximum temperature	W2	Highest temperature in 24 hours
Inches of precipitation	W2	Inches of rain in 24 hours
Pressure	W2	Barometric pressure
Wind speed	W2	Highest gust recorded in 24 hours
Wind direction	W2	Prevailing wind direction for day
Sky cover	W2	Portion of sky covered, sunrise to sunset, in tenths
Weather occurrences	W2	A code representing occurrences of hail, fog, snow, etc.
Relative humidity at 0800 at 1700	W2	 Relative humidity at 8:00 am Relative humidity at 5:00 pm
Tide height	P	Estimated heights of two low and two high tides each day, at the Golden Gate
Tide time	P	Times corresponding to low and high tides

WS FORM F-6 (6-76)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

Observer: Roger A. Cunningham 1116 Roleen Drive
Time of obsn.: 0000 [midnight; 08 Z]

PRELIMINARY LOCAL CLIMATOLOGICAL DATA

STATION: VALLEJO 4N CALIFORNIA
MONTH: NOVEMBER YEAR: 1989

LATITUDE: 38° 09' N LONGITUDE: 122° 15' W GROUND ELEVATION (ft): 23 FT. STANDARD TIME: PACIFIC

DAY (1)	TEMPERATURE °F MAXIMUM (2)	MINIMUM (3)	24hr AVERAGE (4)	DEPARTURE FROM NORMAL (5)	DEGREE DAYS (Base 65°) HEATING (6a)	COOLING (6b)	PRECIPITATION (In.) TOTAL (Water equivalent) (7)	SNOWFALL, ICE PELLETS (8)	SNOW, ICE PELLETS OR ICE ON GROUND AT (9)	PRESSURE AT 00Z/in (10)	WIND FASTEST MILE * SPEED (m.p.h.) (11)	Prevailing wind dir. (12)	SUNSHINE TOTAL (Min.) (13)	PERCENT OF POSSIBLE (14)	SKY COVER SUNRISE TO SUNSET (Tenths) (15)	WEATHER OCCURRENCES (16)	TEMP AT 0000 (17)	RH% AT 0700 (18)	RH% AT 1600 (19)	RH% AT 2200 (20)
1	71.1	41.0	55.0	+1	10	0	.00			30.14	10	E			0	8	47	65	33	56
2	72.8	39.9	54.5	+1	10	0	.00			30.09	3	SW			0	8	47	76	46	60
3	74.8	40.3	55.0	+1	10	0	.00			30.04	5	SE			3	8	48	76	41	62
4	73.8	43.2	56.1	+2	9	0	.00			29.93	5	E			0	8	51	88	51	84
5	68.2	45.4	54.7	+1	10	0	.00			29.96	7	SW			3	2 til 0715	47	97	56	67
6	64.1	40.2	50.3	-4	15	0	.00			30.06	5	SW			7	2:1 til 1100	44	93	68	76
7	68.6	38.8	51.6	-1	13	0	.00			30.04	3	SW			1	8	44	75	44	70
8	68.7	38.5	52.1	-1	13	0	.00			30.10	3	SW			0	8	45	79	46	70
9	71.6	39.3	53.5	+1	11	0	.00			30.08	7	E			0	8	47	88	44	67
10	73.9	42.1	55.4	+2	10	0	.00			29.97	5	E			0	8	49	77	42	65
11	74.2	43.1	56.1	+3	9	0	.00			29.90	5	E			4	8	48	77	48	65
12	62.3	44.7	52.7	0	12	0	.00			29.94	7	SW			7	2 til 1215	53	97	78	91
13	59.9	44.2	52.5	+1	12	0	T			30.04	6	SW			7	1 til 1300	53	94	78	91
14	67.9	43.1	54.4	+2	11	0	.00			30.08	3	SW			2	1 til 0845	43	88	35	65
15	65.5	41.3	50.9	-1	14	0	.00			30.17	5	NE			7		43	74	57	68
16	70.7	37.4	52.0	0	13	0	.00			29.99	3	SW			2	8	45	91	47	60
17	73.8	41.5	57.3	+5	8	0	.00			29.85	10	E			2	8	60	80	47	49
18	73.9	48.4	61.0	+10	4	0	.00			30.07	12	E			1	8	49	67	41	63
19	75.2	43.2	55.8	+5	9	0	.00			30.06	5	E			0	8	48	81	45	62
20	73.7	40.9	54.9	+4	10	0	.00			30.02	3	SW			0		47	77	40	62
21	60.5	39.7	49.1	-1	16	0	.00			30.08	2	SW			8	1 til 1115	47	76	72	79
22	54.2	44.1	48.8	-1	16	0	.00			30.09	5	SW			8	1 til 1400	48	86	63	66
23	53.9	45.9	50.2	0	15	0	.02			30.01	7	W			10	1	51	93	67	91
24	61.0	50.3	54.6	+6	10	0	.04			29.92	3	SW			7	2 til 0830	52	97	80	84
25	55.5	49.1	51.6	+3	13	0	2.15			29.72	14	SW			10		50	97	97	73
26	58.3	40.4	48.6	0	16	0	.03			30.23	12	W			3		41	74	41	80
27	64.4	35.0	47.9	0	16	0	.00			30.22	5	E			0	lt. frost	47	91	26	58
28	60.0	40.7	50.3	+2	15	0	.00			30.25	10	E			0		50	65	33	40
29	62.9	42.5	50.9	+3	14	0	.00			30.17	12	E			6		45	49	37	56
30	62.9	38.2	49.9	+3	15	0	.00			30.27	8	E			3		43	65	43	62
31																				
SUM	1998	1262	—	—	360	0	2.24		—		—	—		—	102	—				
AVG	66.6	42.1	—	—	—	—	—	—	—	30.05	FASTEST	DIRECTION	POSSIBLE	%	3.4	—		80	51	68
										MISC. →	14	SW				—				

* peak gust, mph

TEMPERATURE DATA

AVERAGE MONTHLY 52.9
DEPARTURE FROM NORMAL +1.5
HIGHEST 75.2 ON 19
LOWEST 35.0 ON 27

NUMBER OF DAYS WITH –
MAX. 32° OR BELOW 0
MAX. 90° OR ABOVE 0
MIN. 32° OR BELOW 0
MIN. 0° OR BELOW 0

HEATING DEGREE DAYS (Base 65°)
TOTAL THIS MONTH 360
DEPARTURE FROM NORMAL -48
SEASONAL TOTAL 734
DEPARTURE FROM NORMAL +11

COOLING DEGREE DAYS (Base 65°)
TOTAL THIS MONTH 0
DEPARTURE FROM NORMAL 0
SEASONAL TOTAL 166
DEPARTURE FROM NORMAL +1

PRECIPITATION DATA

TOTAL FOR THE MONTH 2.24 IN.
DEPARTURE FROM NORMAL -0.55 IN.
GREATEST IN 24 HRS. 2.15 ON 25

SNOWFALL, ICE PELLETS
TOTAL FOR THE MONTH ______ IN.
GREATEST IN 24 HRS. ______ ON ______
GREATEST DEPTH ON GROUND ______ ON ______

WEATHER

NUMBER OF DAYS –
CLEAR (Scale 0–3) 19
PARTLY CLOUDY (Scale 4–7) 7
CLOUDY (Scale 8–10) 4
WITH 0.01 INCH OR MORE PRECIP. 4
WITH 0.10 INCH OR MORE PRECIP. 1
WITH 0.50 INCH OR MORE PRECIP. 1
WITH 1.00 INCH OR MORE PRECIP. 1

SYMBOLS USED IN COLUMN 16

1 = FOG
2 = FOG WITH VISIBILITY ¼ MILE OR LESS
3 = THUNDER
4 = ICE PELLETS
5 = HAIL
6 = GLAZE OR RIME
7 = DUSTSTORM OR SANDSTORM
8 = SMOKE OR HAZE
9 = BLOWING SNOW
☒ = TORNADO

MAXIMUM PRECIPITATION

Δt (Minutes)	5	10	15	20	30	45	60	80	100	120	150	180
PRECIPITATION (Inches)												
ENDED: DATE												
TIME												

SEASON PRECIP. TO DATE: 4.79
NORMAL PRECIP. TO DATE: 4.73
% OF NORMAL 101%

HIGHEST SEA-LEVEL 30.27 IN. ON 30
LOWEST SEA-LEVEL 29.72 IN. ON 25

WS FORM F-6 SUPERSEDES WS FORM F-6 (9-74) WHICH SHOULD BE USED UNTIL EXISTING STOCK IS DEPLETED.

☆ U.S. G.P.O. 1978-765-092/1151 REG.#6

Figure G-2. Data sheet for weather measurments taken at Location W2.

Weather variables and the mortality variable were tested for normality using the Shapiro-Wilk W statistic. We applied transformations, most commonly square root or log transformations, where these improved the distribution of variables. For example, the square root of the cloud ceiling was used rather than the untransformed variable.

Wind speed was trigonometrically partitioned into north-south and east-west components. These components were chosen because they are parallel and perpendicular to the route of the transmission line where it parallels Skaggs Island Road (Figure 2-1).

Measures of visibility at Location 1 were ordinally scaled and were not transformed.

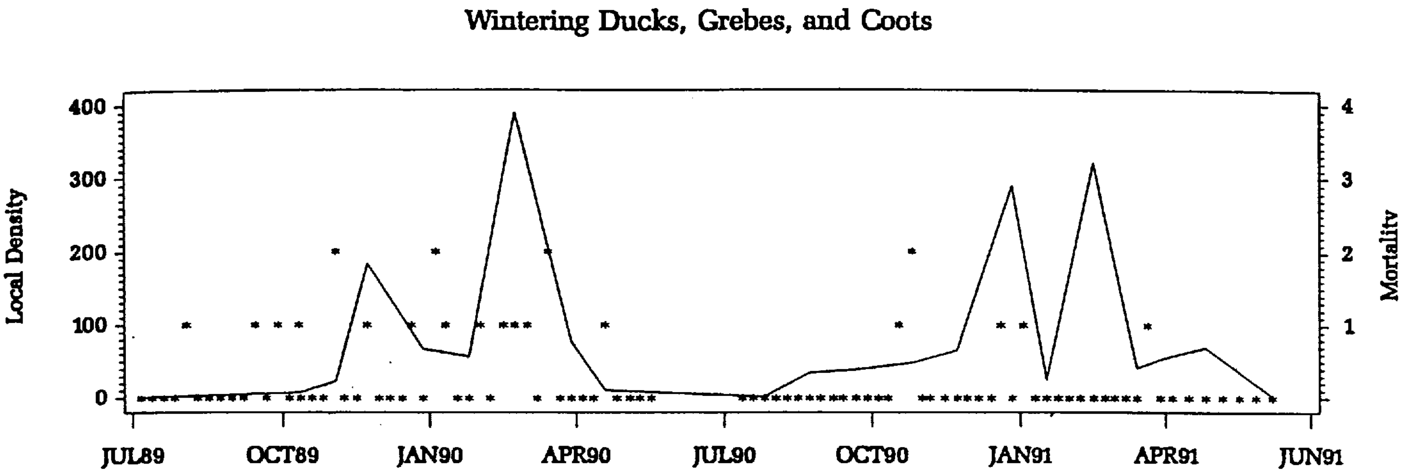
Estimates of bird density used as predictor variables in the models were derived from the PG&E flight survey or pond census counts described in the main body of this report. Densities were calculated as the average over the sample days in a survey period. Linear interpolation was used to calculate predicted densities on non-sample days. Since these surveys were conducted only in Years 2 and 3 of the study, this analysis is limited to those years. Figure G-3 shows the densities of wintering ducks, shorebirds, and landbirds at the site, and the number of deadbirds found on the second search day of each search period.

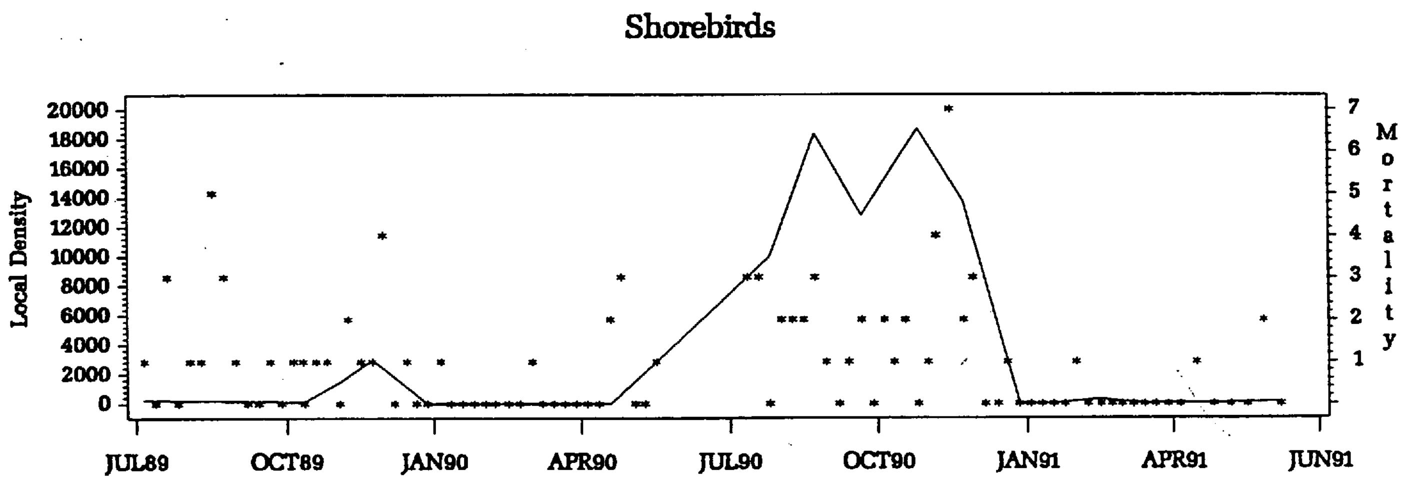
Because birds differ in their seasonal presence at the study site and in their behavior, the effect of weather on mortality was analyzed separately for major bird groups. Three major groups were studied: wintering ducks, shorebirds, and landbirds. The species included in each group are listed in Table G-2. Wintering "ducks" include coots, grebes, and most ducks other than cormorants. Shorebirds included most species other than avocets, stilts, and yellowlegs, none of which experienced mortality during this study. "Landbirds" is a generalized group consisting of passerines, hummingbirds, doves, and other small terrestrial species. Several major bird groups were not included in the analysis because they suffered no mortality, or were rarely seen during surveys. These groups include gulls and terns, herons and egrets, rails, pelicans, and raptors.

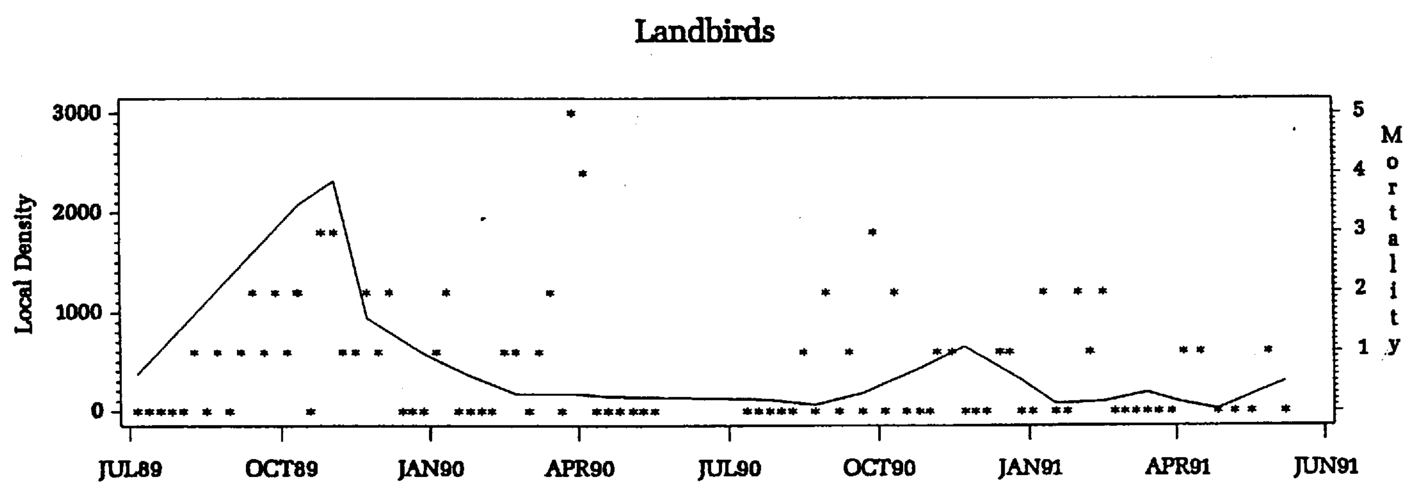
In previous years, we had extracted three data sets from the original data set for analysis. The first set was a weekly model, which included mortality for 2 days of searches in the week, and weather variables representing the average weather for the preceding week. The second set included mortality from the second day of each 2-day search period, and weather for that morning and the preceding day, and the third set included similar data for the first day of each search period. As might be expected, the second data set (Day 2) gave the most consistently interpretable results. Only the Day 2 model is analyzed here.

Table G-2. Bird species included in analysis groups.

Group	Wintering Birds	Shorebirds	Landbirds
Search Day 2 Mortality	24	83	66
Species	Red-throated loon Grebe species Pied-billed grebe Horned grebe Eared grebe Western grebe Clark's grebe Clark's/western grebe Green-winged teal Northern pintail Cinnamon teal Northern shoveler Gadwall Eurasian wigeon American wigeon Canvasback Redhead Lesser scaup Common goldeneye Bufflehead Ruddy duck American coot	Black-bellied plover Pacific golden-plover Snowy plover Semipalmated plover Killdeer Willet Wandering tattler Whimbrel Long-billed curlew Marbled godwit Ruddy turnstone Sanderling Western sandpiper Least sandpiper Sandpiper species Western/least sandpiper Peep species Dunlin Short-billed dowitcher Long-billed dowitcher Dowitcher species Shorebird species Common snipe Red-necked phalarope	California quail Rock dove Mourning dove White-throated swift Anna's hummingbird Western flycatcher Black phoebe Say's phoebe Horned lark House wren Ruby-crowned kinglet Hermit thrush Varied thrush Water pipit European starling Warbler species Orange-crowned warbler Yellow warbler Yellow-rumped warbler Townsend's warbler Wilson's warbler Rufous-sided towhee Chipping sparrow Savannah sparrow Song sparrow Lincoln's sparrow Golden-crowned sparrow White-crowned sparrow Sparrow species Sparrow/finch species Dark-eyed junco Lapland longspur Red-winged blackbird Tricolored blackbird Western meadowlark Blackbird species Brewer's blackbird Brown-headed cowbird Purple finch House finch American goldfinch Passerine species







____ Local Density * Dead birds found on second search day

Figure G-3. Local density and mortality of three bird groups at the study site. Density was determined by pond censuses or flight surveys. Mortality was the number of dead birds of each group found on the second day of each search period.

Table G-3 lists the variables included in the Day 2 data set. Variables measuring the same underlying factor are grouped together. These tables also list the correlation coefficients and associated probabilities for both simple pairwise correlations, and for partial correlations with the variable representing estimated bird group densities.

Several factors were used to reduce the number of variables entered into the multiple regression analysis. Variables were chosen for their approximation to a normal distribution and for their correlation to mortality. One or two variables was chosen to measure each underlying factor such as wind, visibility, or tide. A stepwise multiple regression was run for each bird group using an F to enter of 0.15.

The Durbin-Watson d statistic was used to test for autocorrelation effects. A significant problem with this analysis is seasonal autocorrelation. Mortality, bird density, and many of the weather measurements vary predictably with the seasons. Such data may violate the assumption of independence required for regression analysis. The seasonality of variables such as minimum temperature is relatively easy to assess. However, tide variables show complex monthly and seasonal trends, and their significance is difficult to assess. Ideally, seasonal data should be analyzed using time-series regression, which was not available for this study.

Preliminary models were tested for collinearity, outliers, and other data anomalies which would affect the reliability of the models. Visual examination of residuals plotted against predictor variables revealed no obvious departures from the normal distribution.

Table G-3. Variables included in the Day2 data set.

Variable	Description	Minimum	Maximum
MAXTEMP	Maximum temperature recorded in 24 hour day before search	47.70	97.70
MINTEMP	Minumum temperature recorded in 24 hour day before search	28.20	62.30
CAVTEMP	Average of MINTEMP and MAXTEMP	39.50	76.85
VIS_NAPA	Visibility from Napa Bridge on morning of day before search	1.00	3.00
VIS_N	Visibility from Hwy 37 and levee road to N day before search	1.00	3.00
VIS_E	Visibility from Hwy 37 and levee road to E day before search	1.00	3.00
CLDHGT_C	Height of cloud cover above ground on morning before search	0	10000.00
SCLDHGT	Square root of CLDHGT_C	0	100.00
VIS_NAP2	Visibility from Napa Bridge on morning of search	1.00	3.00
VIS_N2	Visibility from Hwy 37 and levee road to N on morning of search	1.00	3.00
VIS_E2	Visibility from Hwy 37 and levee road to E on morning of search	1.00	3.00
CLDHGTC2	Height of cloud cover above ground on morning of search	0	10000.00
SCLDHGT2	Square root of CLDHGTC2	0	100.00
SKYCOVER	Average portion of sky covered during daylight hours, tenths	0	10.00
OCCURCD	Categorical variable denoting fog, hail, and other anomalies	0	8.00
CLOUDCOV	Percent cloud cover at site on morning of search	0	100.00
CEILING	Height of cloud cover on Napa River on morning of search	0	10000.00
VISIBILI	Visibility in miles on morning of search	0	15.00
WINDSPD	Wind velocity at site morning of day before search	0	24.00
NSWIND_S	North-south component of WINDSPD	0	16.97
EWWIND_S	East-west component of WINDSPD	0	16.97
WINDSPD2	Wind velocity at site morning of search	0	12.00
SWINDSP2	Square root of WINDSPD2	0	3.46
NSWIND2	North-south component of WINDSPD2	0	7.07
EWWIND2	East-west component of WINDSPD2	0	12.00
SNSWIND2	Square root of NSWIND2	0	2.66
LEWWIND2	Natural log of EWWIND2	0	2.564
CMAXWIND	Maximum wind speed recorded in 24 hour day before search	2.00	25.00
NSWIND_M	North-south component of CMAXWIND	0	25.00
EWWIND_M	East-west component of CMAXWIND	0	25.00
MINTIDE	Height of lowest tide of day	-2.10	1.40
TIMEMIN	Time of lowest tide of day	00:30	24:39
MAXTIDE	Height of highest tide of day	5.00	7.50
TIMEMAX	Time of highest tide of day	00:08	24:37
MINTIDE1	Height of first low tide of day	-2.10	3.60
TIMEMIN1	Time of first low tide of day	00:08	13:50
MAXTIDE1	Height of first high tide of day	3.80	6.90
TIMEMAX1	Time of first high tide of day	00:08	13:46
MINTIDE2	Height of second low tide of day	-1.90	3.50
TIMEMIN2	Time of second low tide of day	11:55	24:47
MAXTIDE2	Height of second high tide of day	3.70	7.50
TIMEMAX2	Time of second high tide of day	11:07	24:37
TIDERIS2	Height of tide at Edgerley Island at sunrise	.11	6.42
TIDESET	Height of tide at Edgerley Island at sunset	-.24	6.47
MOONDAY	Varies from 1 at new moon to 15 or 16 at full moon	1.00	18.00
MOONLITE	Moonlight as function (moonday, visibility)	1.00	21.00
INPPT	Inches of precipitation on day before search	0	.51
SINPPT	Square root of INPPT	0	.71
PRESSURE	Barometric pressure on day before search	29.30	30.32
RH0800	Relative humidity at 8:00am on day before search	12.00	104.50
RH1700	Relative humidity at 5:00pm on day before search	0	100.00

CORRELATIONS WITH BIRD GROUP MORTALITY

Variable	Wintering Ducks				Shorebirds				Landbirds			
	Simple		Partial		Simple		Partial		Simple		Partial	
	Rho*	P > 0**	Rho	P > 0	Rho	P > 0	Rho	P > 0	Rho	P > 0	Rho	P > 0
MAXTEMP	-.06	.60	.04	.73	.11	.31	-.01	.95	.04	.69	.04	.72
MINTEMP	-.19	.07	-.12	.25	.18	.08	.10	.34	-.05	.66	-.03	.76
CAVTEMP	-.12	.24	-.04	.72	.15	.15	.04	.67	.00	.98	.01	.95
VIS_NAPA	.04	.72	.01	.91	.05	.63	.07	.53	.02	.82	-.01	.95
VIS_N	.05	.66	.01	.91	.04	.70	.08	.46	.05	.66	.00	.99
VIS_E	.06	.59	.02	.84	.02	.82	.05	.64	.06	.58	.02	.88
CLDHGT_C	.03	.78	.05	.61	-.16	.14	-.12	.25	-.09	.40	-.11	.30
SCLDHGT	.04	.70	.07	.53	-.16	.14	-.13	.21	-.09	.39	-.11	.30
VIS_NAP2	.02	.83	.01	.90	-.07	.51	-.04	.72	.02	.88	-.03	.78
VIS_N2	-.00	.98	-.02	.82	-.08	.48	.00	1.00	-.00	.97	-.04	.73
VIS_E2	-.03	.81	-.05	.63	-.04	.68	-.02	.89	-.02	.84	-.05	.65
CLDHGTC2	.07	.51	.09	.41	-.08	.46	-.08	.44	.14	.20	.08	.42
SCLDHGT2	.10	.34	.12	.26	-.06	.54	-.05	.61	.13	.20	.09	.42
SKYCOVER	-.12	.26	-.21	.05	-.04	.72	-.05	.63	.02	.82	.07	.54
OCCURCD	.10	.33	.12	.28	.13	.23	.10	.35	.22	.04	.13	.23
CLOUDCOV	.03	.83			.43	.00			-.05	.75		
CEILING	.04	.70	-.01	.92	-.14	.19	-.16	.14	-.01	.89	.02	.84
VISIBILI	-.01	.91	-.06	.57	-.14	.20	-.16	.14	.07	.51	.14	.19
WINDSPD	-.11	.31	-.10	.35	.02	.87	.04	.72	-.09	.38	-.02	.85
NSWIND_S	-.07	.49	-.07	.49	-.01	.90	.04	.72	-.07	.51	-.00	.98
EWWIND_S	-.15	.16	-.13	.22	.04	.69	.04	.67	-.08	.43	-.01	.91
WINDSPD2	-.15	.14	-.16	.13	.04	.69	.02	.84	-.02	.89	.07	.50
SWINDSP2	-.12	.24	-.13	.23	.03	.77	.03	.80	.00	.97	.06	.56
NSWIND2	-.13	.22	-.14	.19	.00	.97	.00	.99	.01	.89	.10	.36
EWWIND2	-.14	.18	-.15	.17	.06	.56	.03	.76	-.02	.87	.07	.52
SNSWIND2	-.09	.39	-.10	.34	-.05	.65	-.04	.73	.02	.85	.08	.45
LEWWIND2	-.10	.34	-.11	.29	.07	.52	.05	.65	.02	.86	.08	.45
CMAXWIND	-.15	.15	-.13	.21	-.01	.90	.03	.80	-.32	.00	-.23	.03
NSWIND_M	-.04	.68	-.03	.76	-.03	.77	.04	.68	-.17	.10	-.08	.46
EWWIND_M	-.20	.06	-.17	.10	.05	.62	.05	.64	-.21	.04	-.15	.15
MINTIDE	.03	.80	.02	.84	-.01	.93	-.04	.73	.10	.33	.09	.39
TIMEMIN	.06	.55	.02	.83	-.01	.94	-.02	.81	-.17	.12	-.17	.11
MAXTIDE	-.02	.82	-.03	.79	.10	.35	.11	.31	-.15	.15	-.18	.09
TIMEMAX	-.03	.76	.02	.87	-.00	.99	-.07	.49	.01	.95	-.05	.66
MINTIDE1	.04	.69	-.00	.98	-.01	.90	-.04	.74	.05	.66	-.01	.96
TIMEMIN1	.25	.02	.24	.02	-.06	.58	-.03	.76	-.13	.21	-.13	.21
MAXTIDE1	.12	.24	.08	.48	.01	.95	.04	.68	-.08	.46	-.04	.70
TIMEMAX1	.07	.51	.09	.39	-.02	.84	-.07	.51	.11	.28	.05	.63
MINTIDE2	-.06	.56	-.02	.85	-.02	.86	-.02	.85	.04	.73	.08	.43
TIMEMIN2	.24	.02	.22	.03	-.03	.78	-.01	.90	-.10	.32	-.13	.22
MAXTIDE2	-.06	.54	-.02	.87	.10	.32	.05	.67	-.07	.51	-.12	.24
TIMEMAX2	.04	.74	.04	.72	-.06	.57	-.06	.60	.05	.66	.03	.78
TIDERIS2	.15	.15	.10	.36	-.10	.34	-.10	.37	.05	.64	.04	.74
TIDESET	.03	.79	.09	.38	-.02	.87	-.09	.39	.02	.82	.02	.88
MOONDAY	.03	.78	.05	.61	.14	.20	.10	.35	.05	.65	.06	.59
MOONLITE	-.02	.82	.02	.85	.07	.48	.00	.97	-.00	.96	.04	.74
INPPT	-.07	.52	-.11	.29	-.12	.26	-.10	.36	-.01	.93	.02	.86
SINPPT	-.05	.64	-.09	.41	-.10	.34	-.10	.34	-.06	.60	-.03	.78
PRESSURE	.11	.31	.08	.45	-.04	.69	-.04	.73	.02	.88	.00	.99
RH0800	-.14	.18	-.14	.18	.13	.20	.03	.80	.15	.15	.21	.04
RH1700	-.14	.20	-.18	.08	-.02	.86	.10	.34	.02	.85	.02	.84

* Rho is the Pearson Correlation Coefficient
** Probability that correlation is not significantly different from 0

RESULTS

EFFECTS OF WEATHER AND LOCAL BIRD POPULATION SIZE ON BIRD MORTALITY

Tables G-4 through G-6 give statistics associated with the regression models. Each table shows the variables included when the regressions are run for each year separately, and for the two years combined. The processes of analyzing bird groups separately and combining two years' data both contribute to decreased resolution of the models from that seen in previous years.

These previous years' models included all dead birds found from about mid-September on. Densities were modeled after waterfowl abundance. R-square (the proportion of the total variance in bird mortality explained by the weather data sets) was 59% for the Day2 model for Year 2, and 62% for Year 1. Both models were highly significant statistically.

The regression of weather variables by year on the three major bird groups yielded models with R^2 varying from 16% to 65%. For two years combined, the R^2 values were 18% for ducks, 20% for shorebirds, and 25% for landbirds. Despite the low R^2 values, all regressions were statistically significant. When the 1989-90 and 1990-91 data for shorebirds are analyzed separately, the amount of variation in mortality explained by the models increases dramatically, and other variables enter the models, as shown in Tables G-4 through G-6.

Bird densities contributed to models for all three groups. For ducks and relatives, duck density is a very weak predictor of mortality. It explains 3% of variation in mortality in the combined years' model, 7% of the second year's variation, but does not enter the model for the third year. For shorebirds, bird density is the only significant predictor of mortality when both years' data are combined. Shorebird density explains about 9% of the Table G-4 variation in the second year's shorebird mortality, and 30% of the third year's. For landbirds, observed density is also a weak predictor of mortality. It explains about 4% of the variation in mortality for the combined years' model, does not enter the second year model, and explains about 5% of the third year's variation in mortality.

The relation between weather variables and mortality is different for each of the three groups examined. For ducks, this relation is difficult to interpret. Both the second year and combined year models show that mortality increases when the previous day had a higher east-west wind component. Tide variables also enter all models. In the third year, mortality increases with better visibility the morning of the search and with rain and (paradoxically) higher barometric pressure the preceding day. The combined model also indicates a significant difference in mortality between the second and third years.

Table G-4. Statistics for stepwise regression of weather variables on weekly mortality. Dependent variable "Group 11" is mortality of wintering ducks, coots, and grebes.

YEAR 2 MODEL

R-square	0.2789
Adj R-sq	0.2102

Variable	Parameter Estimate	Parameter=0	Prob > |T|
PDENS11	0.001769	2.129	0.0392
TIMEMIN	-0.000006199	-1.789	0.0808
EWWIND_M	-0.030858	-1.896	0.0649
TIMEMIN1	0.000020641	2.761	0.0085

YEAR 3 MODEL

R-square	0.4676
Adj R-sq	0.3835

Variable	Parameter Estimate	T for H0: Parameter=0	Prob > |T|
INTERCEP	-46.387232	-4.130	0.0002
MAXTEMP	0.011031	2.041	0.0483
VIS_NAP2	-0.262459	-2.830	0.0074
TIMEMIN	0.000008636	3.616	0.0009
TIDESET	0.082918	2.560	0.0146
SINPPT	1.470515	3.105	0.0036
PRESSURE	1.510625	4.073	0.0002

COMBINED MODEL

Summary of Stepwise Procedure for Dependent Variable GROUP11

Step	Variable Entered	Removed	Number In	Partial R**2	Model R**2	F	Prob>F
1	TIMEMIN1		1	0.0640	0.0640	6.1547	0.0150
2	YEAR		2	0.0652	0.1292	6.6592	0.0115
3	PDENS11		3	0.0325	0.1617	3.4103	0.0682
4	EWWIND_M		4	0.0220	0.1837	2.3455	0.1293

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	4	4.72733	1.18183	4.893	0.0013
Error	87	21.01180	0.24151		
C Total	91	25.73913			

Root MSE	0.49144	R-square	0.1837
Dep Mean	0.26087	Adj R-sq	0.1461
C.V.	188.38599		

Parameter Estimates

Variable	Parameter Estimate	T for H0: Parameter=0	Prob > |T|
INTERCEP	0.737880	2.619	0.0104
PDENS11	0.000934	1.606	0.1118
YEAR	-0.272501	-2.642	0.0098
EWWIND_M	-0.014720	-1.532	0.1293
TIMEMIN1	0.000010672	2.565	0.0120

Durbin-Watson D	2.251
(For Number of Obs.)	92
1st Order Autocorrelation	-0.129

Table G-5. Statistics for stepwise regression of weather variables on weekly mortality. Dependent variable "Group 16" is mortality of shorebirds.

YEAR 2 MODEL

R-square	0.4134
Adj R-sq	0.3419

Variable	Parameter Estimate	T for H0: Parameter=0	Prob > |T|
INTERCEP	117.443776	3.521	0.0011
PDENS16	0.000512	2.887	0.0062
TIMEMAX1	-0.000030805	-2.921	0.0056
SNSWIND2	-0.375713	-2.253	0.0297
SINPPT	-1.769370	-1.520	0.1361
PRESSURE	-3.855747	-3.468	0.0012

YEAR 3 MODEL

R-square	0.6528
Adj R-sq	0.5980

Variable	Parameter Estimate	T for H0: Parameter=0	Prob > |T|
INTERCEP	-95.410579	-3.646	0.0008
PDENS16	0.000139	6.606	0.0001
CEILING	-0.000135	-3.322	0.0020
VIS NAP2	-0.791082	-2.938	0.0056
TIDESET	-0.193767	-2.351	0.0240
PRESSURE	3.222749	3.698	0.0007
RH1700	0.027910	4.182	0.0002

COMBINED MODEL

Summary of Stepwise Procedure for Dependent Variable GROUP16

Step	Variable Entered	Removed	Number In	Partial R**2	Model R**2	F	Prob>F
1	PDENS16		1	0.1711	0.1711	18.5773	0.0001
2	YEAR		2	0.0255	0.1966	2.8254	0.0963

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	2	30.69339	15.34670	10.890	0.0001
Error	89	125.42617	1.40928		
C Total	91	156.11957			

Root MSE	1.18713	R-square	0.1966
Dep Mean	0.90217	Adj R-sq	0.1785
C.V.	131.58574		

Parameter Estimates

Variable	Parameter Estimate	T for H0: Parameter=0	Prob > |T|
INTERCEP	1.716857	2.455	0.0160
PDENS16	0.000110	4.569	0.0001
YEAR	-0.495363	-1.681	0.0963

Durbin-Watson D	1.657
(For Number of Obs.)	92
1st Order Autocorrelation	0.171

Table G-6. Statistics for stepwise regression of weather variables on weekly mortality. Dependent variable "Group 17" is mortality of landbirds.

YEAR 2 MODEL

R-square	0.1571
Adj R-sq	0.1188

Variable	Parameter Estimate	T for H0: Parameter=0	Prob > |T|
INTERCEP	4.645468	2.774	0.0081
MAXTIDE	-0.491213	-1.855	0.0703
CMAXWIND	-0.061892	-2.262	0.0287

YEAR 3 MODEL

R-square	0.4823
Adj R-sq	0.4159

Variable	Parameter Estimate	T for H0: Parameter=0	Prob > |T|
INTERCEP	0.607230	0.689	0.4946
PDENS17	-0.001099	-1.931	0.0608
VIS E2	-0.495760	-3.237	0.0025
CMAXWIND	-0.081246	-4.686	0.0001
TIMEMAX	0.000012651	3.282	0.0022
RH0800	0.013623	1.787	0.0816

COMBINED MODEL

Summary of Stepwise Procedure for Dependent Variable GROUP17

Step	Variable Entered	Removed	Number In	Partial R**2	Model R**2	F	Prob>F
1	CMAXWIND		1	0.1019	0.1019	10.2148	0.0019
2	MAXTIDE		2	0.0388	0.1408	4.0218	0.0480
3	PDENS17		3	0.0362	0.1769	3.8679	0.0524
4	TIMEMIN		4	0.0235	0.2004	2.5563	0.1135
5	VISIBILI		5	0.0318	0.2322	3.5637	0.0624
6	SNSWIND2		6	0.0244	0.2567	2.7930	0.0984

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	6	24.29412	4.04902	4.892	0.0002
Error	85	70.35806	0.82774		
C Total	91	94.65217			

Root MSE	0.90980	R-square	0.2567
Dep Mean	0.71739	Adj R-sq	0.2042
C.V.	126.82105		

Parameter Estimates

Variable	Parameter Estimate	T for H0: Parameter=0	Prob > |T|
INTERCEP	2.848243	2.376	0.0197
PDENS17	0.000425	2.424	0.0175
TIMEMIN	-0.000007932	-2.042	0.0443
MAXTIDE	-0.349736	-1.897	0.0613
VISIBILI	0.061397	2.112	0.0376
SNSWIND2	0.201520	1.671	0.0984
CMAXWIND	-0.053392	-3.023	0.0033

Durbin-Watson D	1.882
(For Number of Obs.)	92
1st Order Autocorrelation	0.047

Weather variables do not show clear or consistent relations with shorebird mortality. For the second year, shorebird mortality increases with a lower north-south wind component on the morning of the search, decreasing rain, lower barometric pressure on the previous day, and with later first high tide on the preceding day. For the third study year shorebird mortality increases with lower tides at sunset and higher evening humidity on the preceding day. Paradoxically, it increases with better visibility at the site the morning of the search, but also with lower cloud ceilings on that morning. Higher barometric pressure the preceding day is associated with lower mortality, contrary to the second year's results.

The strongest and most consistent relation of a weather variable with mortality is the positive relation between maximum wind speed on the preceding day and landbird mortality. This variable is the greatest contributor to the second year, third year, and combined landbird models. Tide and visibility variables also appear in the models. Paradoxically, visibility is inversely correlated with landbird mortality, with higher mortality associated with better visibility.

DISCUSSION

This attempt to analyze the effects of weather on bird mortality ran into significant methodological and interpretive problems, and the discussion in this report should be regarded as tentative and speculative.

Analyzing data by bird group did not increase the resolution of multiple regression models, as expected. Part of this is due to decreased sample size. However, some difficulty may also be due to using flight survey or pond census data as density estimates. These counts fluctuate, and smoothed curves may better approximate bird density in the area.

The absence of a correction for seasonal trends in weather also make results difficult to interpret. This is particularly true for tidal variables with complex daily and seasonal variation. As mentioned earlier, autoregressive analysis is needed to clarify these relationships.

Despite these difficulties, several trends seem apparent. First of all, shorebird mortality does not seem affected by weather. Shorebirds are present at the Leslie Pond in late summer through fall. Particularly in the past two years, there has been little rainy weather during this period. Around the end of January Leslie Salt allows the pond to fill, eliminating the shorebirds' habitat.

Changes in duck mortality were not clearly related to changes in weather conditions. Tide variables enter strongly into the models, but may only reflect seasonality. Further, weather in the past two winters has been anomalous. However, one trend which shows through three seasons is that mortality decreases with unsettled weather. During the month of March 1991, which saw most of the year's rainfall, no dead ducks were found.

Landbirds show a consistent trend of increased mortality with higher peak wind gusts. One possible explanation is the smaller size of land birds in this study made them more susceptible to being blown into powerlines.

MARE ISLAND TRANSMISSION LINE FLIGHT PATTERN STUDY
FIELD DATA SHEET

DATE (M M D D Y Y) ☐☐☐☐☐☐ SAMPLE LOCATION ☐☐ SPAN (Pole #) ☐☐ From ☐☐ To

TIME (0000-2459) (H H M M) ☐☐☐☐ Start (H H M M) ☐☐☐☐ End OBSERVER ____________

GENERAL COMMENTS ____________

Time	Species	Flock Size	Direction	Alt.	Dist.	Reactions	Comments

Revised 02/27/90

90-1-59

INFORMATION RECORDED FOR EACH SURVEY SITE

Date
Start and end times
Observer
Survey site
Weather (same categories as those used for the morality data sheet [Dedon 1989])

INFORMATION RECORDED FOR EACH BIRD OR FLOCK SEEN CROSSING THE T/L

Time
Species
Flock size
Direction of flight
Altitude category

1. Surface-related: Birds using the habitat under the transmission line and the air space up to 10 feet above the ground.
2. Below 12-kV conductors: Birds crossing the transect under all conductors but at least 3-m above the ground.
3. Through 12-kV conductors: Birds crossing between the 12-kV conductors.
4. Between 12- and 115-kV conductors: Birds crossing above 12-kV conductors and below 115-kV conductors.
5. Through 115-kV conductors: Birds crossing between 115-kV wires.
6. Above conductors: Birds crossing over the highest conductor but within 3 m of the pole top.
7. Above poles: Birds crossing at least 3 m above the pole tops but less than twice the pole height.

Reaction category

1. No reaction: Birds maintain constant altitude and unaltered flight.
2. Swerve and over: Birds turn from course, flying up and over line.
3. Swerve and under: Birds turn from course, flying down and under line.
4. Over and swerve: Birds flying over line swerve immediately after crossing the lines.
5. Turn and leave: Birds turn and retreat from the line (after approaching within 50 m of the line).
6. Collision and fly: Birds in flight hit a conductor but keep flying outside of the transect boundaries. The specific conductor will be noted in the comments section.
7. Collision and fall: Birds in flight hit a conductor and drop within the study transect. The specific conductor will be noted in the comments section.
8. Land on line: Birds land on conductor or pole.

MARE ISLAND TRANSMISSION LINE FLIGHT PATTERN STUDY
FIELD DATA SHEET

DATE (M M D D Y Y) ☐☐☐☐☐☐   SAMPLE LOCATION ☐☐   SPAN (Pole #) ☐☐ From ☐☐ To

TIME (0000-2459) Start (H H M M) ☐☐☐☐ End (H H M M) ☐☐☐☐   OBSERVER ______________________

GENERAL COMMENTS ____

Time	Species	Flock Size	Direction	Alt.	Dist.	Reactions	Comments

Revised 02/27/90

90-1-59

INFORMATION RECORDED FOR EACH SURVEY SITE

Date
Start and end times
Observer
Survey site
Weather (same categories as those used for the morality data sheet [Dedon 1989])

INFORMATION RECORDED FOR EACH BIRD OR FLOCK SEEN CROSSING THE T/L

Time
Species
Flock size
Direction of flight
Altitude category

1. Surface-related: Birds using the habitat under the transmission line and the air space up to 10 feet above the ground.
2. Below 12-kV conductors: Birds crossing the transect under all conductors but at least 3-m above the ground.
3. Through 12-kV conductors: Birds crossing between the 12-kV conductors.
4. Between 12- and 115-kV conductors: Birds crossing above 12-kV conductors and below 115-kV conductors.
5. Through 115-kV conductors: Birds crossing between 115-kV wires.
6. Above conductors: Birds crossing over the highest conductor but within 3 m of the pole top.
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